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U. S. ARMY

HEL STANDARD S-3-65

HUMAN FACTORS ENGINEERING DESIGN STANDARD FOR MISSILE SYSTEMS AND RELATED EQUIPMENT

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HUMAN ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND,
MARYLAND

HEL Standard S-3-65

Human Factors Engineering Design Standard for Missile Systems and Related Equipment

Prepared by

Robert F. Chaillet

Technical Assistance

Alfreda R. Honigfeld

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Approved

JOHN D. WEISZ
Technical Director
Human Engineering Laboratories

U. S. Army Human Engineering Laboratories
Aberdeen Proving Ground, Maryland

INTRODUCTION

1. The data contained in this standard reflect the official position of the U.S. Army Human Engineering Laboratories and supersede all other data issued by these laboratories that pertain to the subject of this standard.

2. Human Engineering Laboratories (HEL) Standards are issued to aid the major subordinate commands of the Army Materiel Command (AMC) in applying human factors engineering criteria to system design.

3. HEL standards provide guidance to the major subordinate commands of AMC for the inclusion of human factors engineering design criteria in research and development or procurement contractual documents.

4. HEL standards serve as the basis for human factors engineering evaluations by the U.S. Army Human Engineering Laboratories in accordance with AMCR 10-4.

5. The purpose of this Standard is to provide human factors engineering design principles and detailed criteria. The design principles are expressed as general rules applicable during missile system research and development programs, or as essential items to be considered during design, to insure the incorporation of sound human factors engineering practices. The detailed criteria consist of dimensions, ranges, tolerances and other specific data. The range of acceptable dimensions and other factors may be rather large in some cases. Where only these minimum and maximum data appear, select any value that is within the recommended range. The goal should be the approximation of the optimum dimensions where given, whenever possible.

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DIMENSIONAL WORKSPACE

Body Dimensions

1. The anthropometric data of this section, shown in Tables 1 and 2 and Figures 1 and 2, provide a basis for design decisions not specifically covered in other sections. Use of these data must take the following into consideration:

   a. The nature, frequency, and difficulty of the related tasks.

   b. The position of the body during performance of these tasks.

   c. Mobility or flexibility requirements imposed by the tasks.

   d. Increments in the design-critical dimensions imposed by the need to compensate for obstacles, projections, etc.

   e. Increments in the design-critical dimensions imposed by protective garments, packages, lines, padding, etc.

   f. Interaction of simultaneous tasks.

2. General rules for use of the data in Tables 1 and 2 and Figures 1 and 2:

   a. Gross dimensions (passageways, accesses, safety clearances, etc.) which must accommodate or allow passage of the body should be based upon the 95th percentile values.

   b. Limiting dimensions (reaching distance, displays, test points, handrails, control movement, etc.) which restrict or are limited by extension of the body should be based upon the 5th percentile values.

   c. Adjustable dimensions (seats, safety goggles, belts, controls, etc.) should be adjustable to accommodate the range of 5th through 95th percentile personnel.

3. The 5th percentile for a particular dimension is a value such that 5 percent of the personnel are smaller than the value expressed and 95 percent of the personnel are larger. Conversely, the 95th percentile for a particular dimension is a value such that 95 percent of the personnel are smaller than the value expressed and 5 percent of the personnel are larger.

4. No individual has bodily measurements that specifically match either the 5th or 95th percentile dimensions. For example, an individual may be the 95th percentile in stature and seated eye-height but have an arm reach or hand measurement well below the 95th percentile dimensions.

5. Seated eye-height measurements, see Fig. 1, E-7, may be reduced by as much as 2.5 inches when personnel sit in a relaxed (slump) position. This is not to be used, nor is it acceptable as justification for lowering an overhead to conserve space. The slump factor should be considered in the design of the movement range of seat adjustment, placement of displays or system visual requirements.

TABLE 1

Body Dimensions

NOTE: Weight in pounds, all other values in inches	Design Values (Percentiles) 5th Nude	Arctic Clothed*	95th Nude	Arctic Clothed*
Weight (pounds)	132.5	158.5	200.8	230.8
A. Standing				
1. Stature	65.2	68.2	73.1	75.8
2. Eye Height	60.8	62.3	68.6	69.7
3. Ear Height	60.0		67.8	
4. Shoulder Height	52.8	54.5	60.2	61.7
5. Nipple Height	47.0		53.9	
6. Kneecap Height	18.4	20.0	21.9	23.7
7. Penale Height	31.6	—	37.4	—
8. Substernale Height	45.6	—	52.1	—
9. Suprasternale Height	52.7	—	59.9	—
B. Standing				
1. Nasal Root Height	61.0		68.9	
2. Chest Depth	8.0	12.6	10.4	13.4
3. Waist Depth	6.7	10.0	9.4	14.0
4. Buttock Depth	7.6		10.2	
5. Crotch Height	30.4	29.0	35.7	32.5
C. Standing				
1. Chest Breadth	10.8	—	13.4	—
2. Waist Breadth	9.4		12.3	
3. Hip Breadth	12.1	15.8	14.4	18.2
4. Knuckle Height	27.7	—	32.4	—
5. Wrist Height	31.0		36.1	
6. Waist Height	39.1	41.2	45.0	46.4
7. Elbow Height	40.6		46.4	
8. Cervicale Height	55.3	57.5	62.9	64.6
D. Seated				
1. Sitting Height	33.6	35.1	38.0	39.9
2. Shoulder Height	21.3	21.8	25.1	25.8
3. Shoulder Elbow Length	13.2	14.6	15.4	16.2
4. Waist Height	7.9		10.4	
5. Thigh Clearance Height	4.8	6.3	6.5	7.5
6. Buttock-Knee Length	21.9	23.9	25.4	26.6
7. Back of Knee Height	15.7	15.8	18.3	17.4
8. Knee Height	20.1	22.7	23.3	25.4
9. Buttock-Leg Length	39.4		45.1	
10. Forearm-Hand Length	17.6	21.6	20.2	22.2
E. Seated				
1. Shoulder Breadth	16.5	18.9	19.4	21.8
2. Elbow-to-Elbow Breadth	15.2	22.7	19.8	26.2
3. Hip Breadth, Sitting	12.7	17.0	15.4	19.6
4. Knee-to-Knee Breadth	7.2		8.8	
5. Breadth of Both Feet	7.0	9.6	8.2	10.4
6. Elbow Rest Height	7.4	6.7	10.8	10.7
7. Eye Height (See Par 4, Page)	29.4	30.2	33.5	33.8

* See note on Arctic Clothing Ensemble, Page 10.

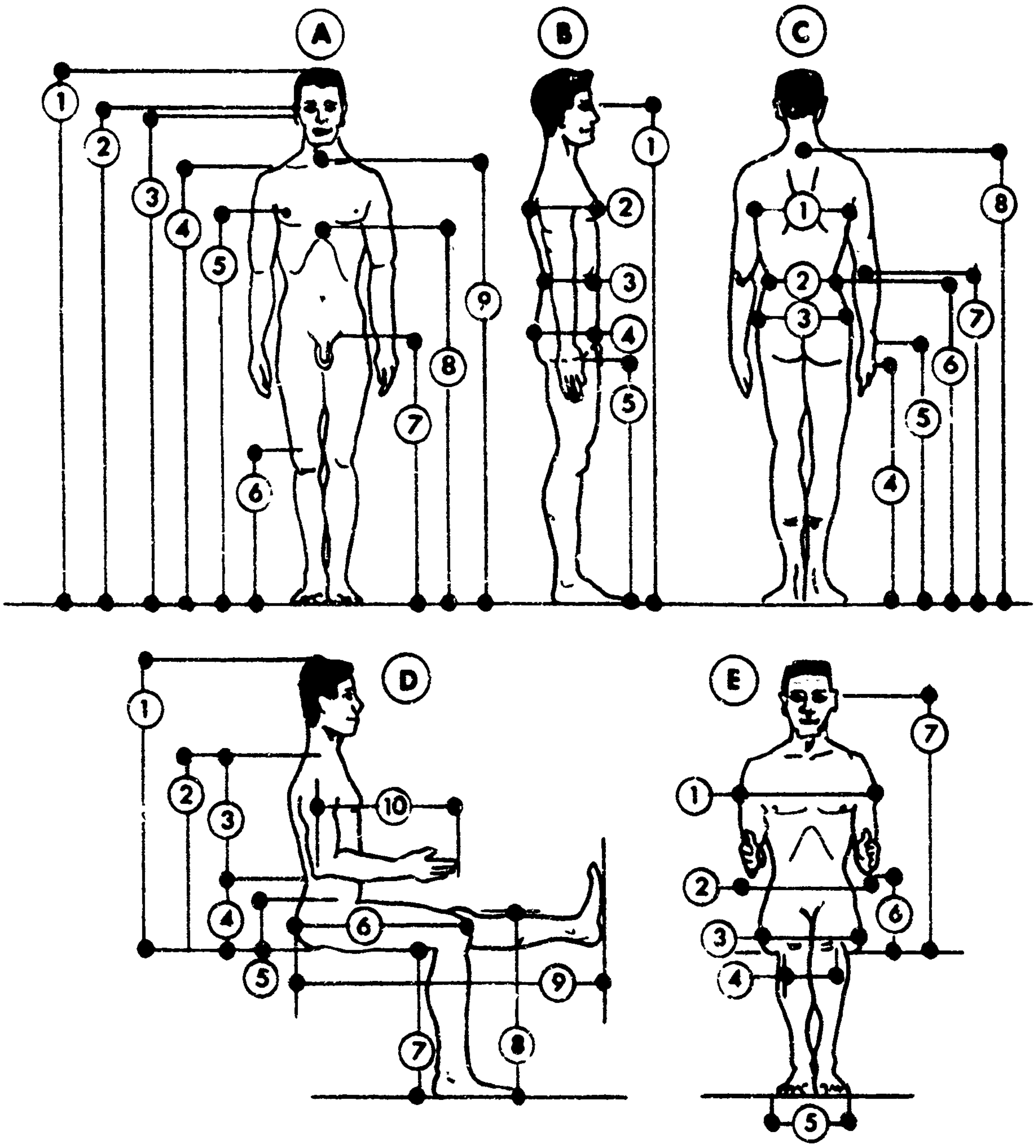


Fig. 1. Body Dimensions

TABLE 1 Continued

NOTE: All values in inches

	5th Nude	Arctic Clothed	95th Nude	Arctic Clothed
	Design Values (Percentiles)			
F. Reach				
1. Functional Reach from Wall	29.7	30.8	35.0	36.7
2. Arm Reach from Wall	31.9	-	37.2	-
3. Maximum Reach from Wall	35.4	-	41.7	-
4. Span	65.9	68.9	75.6	77.0
G. Head				
1. Biocular Diameter	3.5	-	4.1	-
2. Interpupillary Distance	2.3	-	2.7	-
3. Interocular Diameter	1.1	-	1.4	-
4. Nasal Root Breadth	0.5	-	0.7	-
5. Nose Breadth	1.2	-	1.5	-
6. Lip Length	1.8	-	2.3	-
H. Head				
1. Head Breadth	5.7	9.1	6.4	9.0
2. Edge of Right Ear to Left Ear	5.3	-	5.9	-
3. Minimum Frontal Diameter	4.0	-	4.7	-
4. Maximum Frontal Diameter	4.4	-	5.1	-
5. Breadth of the Face	5.2	-	5.9	-
6. Width of the Jaw	3.9	-	4.6	-
7. Ear Protrusion	0.6	-	1.1	-
I. Head				
1. Head Height (from ear)	4.6	6.4	5.6	7.8
2. Minimum Frontal Arc	4.8	-	6.1	-
3. Chin to Nose Length	2.2	-	3.1	-
4. Nose Length	1.8	-	2.2	-
5. Chin to Hairline Length	6.8	-	8.0	-
J. Head				
1. Head Length	7.3	11.0	8.3	11.1
2. Nasal Root to Wall	7.2	-	8.2	-
3. Ear Breadth	1.3	-	1.6	-
4. Ear Length	2.2	-	2.7	-

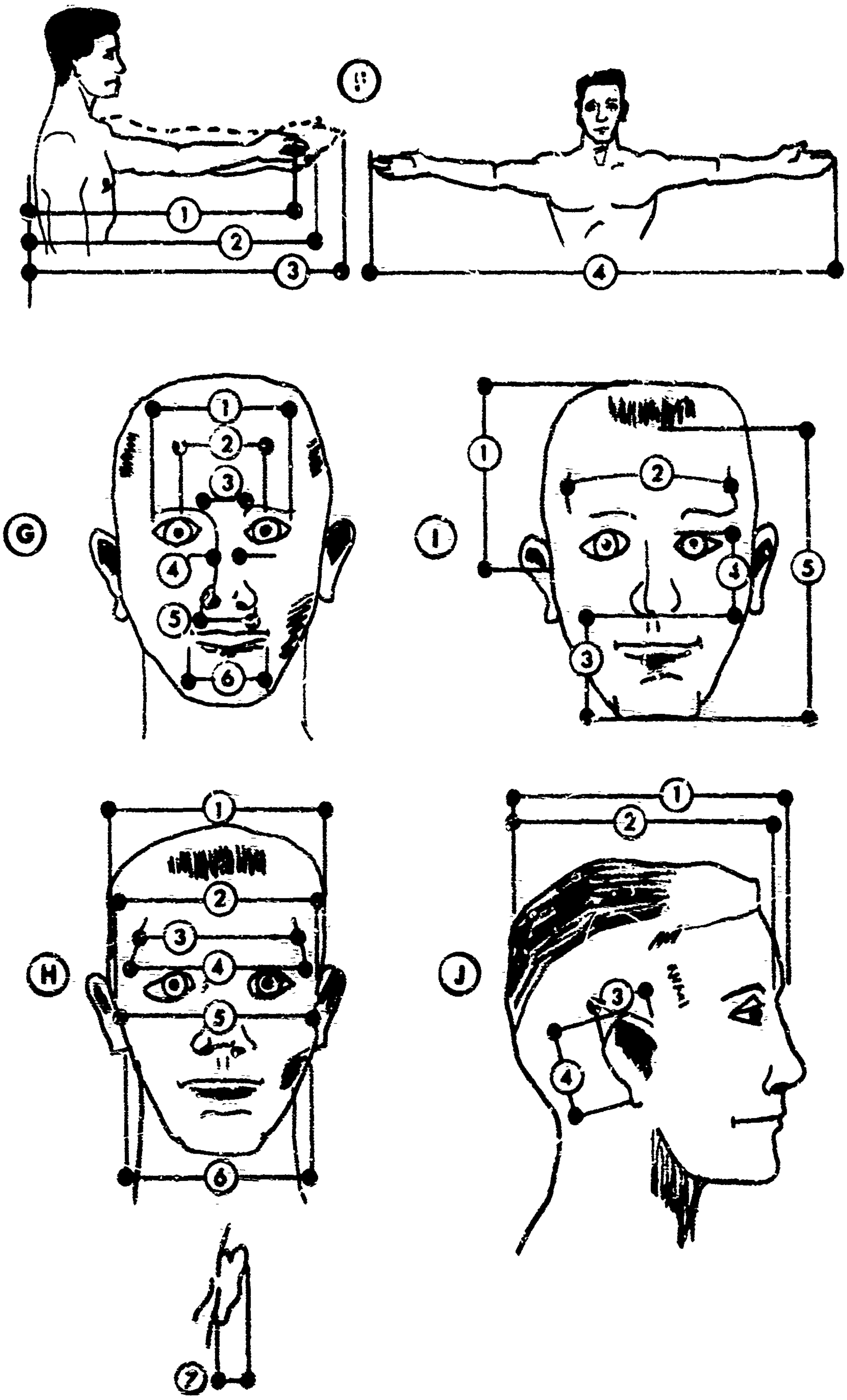


Fig. 1. Continued

TABLE 1 Continued

NOTE: All values in inches

	Design Values (Percentiles)			
	5th Nude	Arctic Clothed	95th Nude	Arctic Clothed
K. Body Circumferences				
1. Neck Circumference	13.8	26.8	16.2	25.9
2. Shoulder Circumference	41.6	52.1	49.4	59.6
3. Chest Circumference	35.1	43.9	43.2	52.1
4. Waist Circumference	27.8	38.5	37.5	49.1
5. Buttock Circumference	34.3	47.2	41.8	55.4
6. Thigh Circumference	19.6	24.8	25.3	30.4
7. Lower Thigh Circumference	15.1	—	19.6	—
8. Calf Circumference	12.9	19.7	16.0	22.4
9. Ankle Circumference	8.1	15.3	9.8	18.0
10. Wrist Circumference	6.3	12.1	7.5	13.1
L. Foot				
1. Ankle Breadth	2.7	—	3.2	—
2. Ankle Height (Medial)	3.1	—	3.8	—
3. Ankle Height (Lateral)	2.4	—	3.1	—
4. Foot Breadth	3.5	4.8	4.1	5.2
5. Ball of Foot Circumference	8.9	14.7	10.4	15.4
6. Foot Length	9.8	12.8	11.5	13.4
7. Instep Length	7.1	8.6	8.2	8.9
8. Heel Breadth	2.4	—	2.9	—
M. Hand				
1. Grip Diameter (Outside)	3.7	See	4.4	
2. Grip Diameter (Inside)	1.6	Fig 3	2.1	
3. First Phalanx III Length	2.5		2.9	
4. Fist Circumference	10.7		12.4	
5. Thickness at Metacarp. III	1.0		1.3	
6. Finger Diameter III	0.8		0.9	
7. Hand Length	6.9		8.0	
8. Hand Breadth at Metacarp	3.2		3.7	
9. Palm Length	3.9		4.6	
10. Hand Breadth at Thumb	3.7		4.4	
11. Digit to Crotch Height	4.0		5.0	
12. Thumb Thickness	0.7		0.8	
13. Thumb Length	2.0		2.6	
14. Third Finger Length	4.2		4.8	
15. Dorsum Length	2.8		3.2	

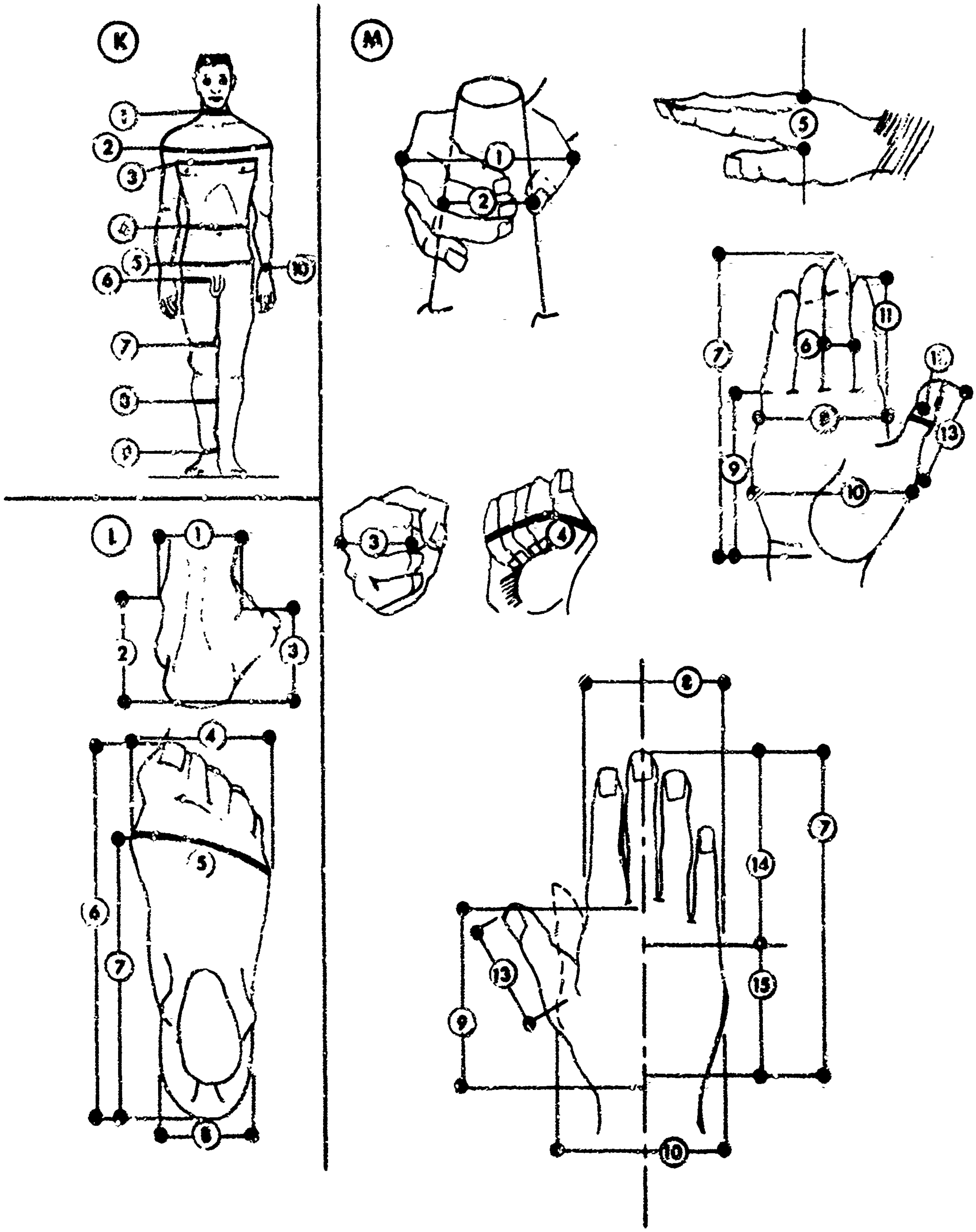


Fig. 1. Continued

Note:

The data for the arctic clothed soldier indicated in Table 1 (pages 4, 6, and 8) were obtained for the 5th and 95th percentile soldier dressed in the following:

a. Headgear

Helmet, steel, with liner
Cap, field, insulating
Hood, field, insulating

b. Handgear

Mittens, lightweight, cold-dry

c. Footgear

Socks, men's, wool, cushion sole
Boots, combat, rubber, insulated, cold-dry (white)

d. Underwear

Undershirt, man's, cotton, short sleeve
Drawers, man's, cotton, shorts (boxer)
Undershirt, lightweight
Drawers, lightweight

e. Body Clothing

Coat, man's, shell
Trousers, man's, shell
Liner, CBR protective, coat, man's, shell
Liner, CBR protective, trousers, man's, shell
Shirt, men's, cotton
Suspenders, trousers
Liner, cold-wet, coat, man's, shell
Liner, cold-wet, trousers, man's, shell
Overgarment, man's, cold-dry, upper body
Overgarment, man's, cold-dry, lower body
Liner, cold-dry, overgarment, man's, upper body
Liner, cold-dry, overgarment, man's, lower body
Vest, armored

TABLE 2

BODY DIMENSIONS OF THE TEMPERATE ZONE CLOTHED 5TH AND 95TH PERCENTILE SOLDIER

	Basic Uniform: Underwear, Khakis or O.D.'s or Fatigues, Socks, Shoes, Helmet and Liner		Additions to the Basic Uniform: Blouse or Field Jacket		Additions to the Basic Uniform: Blouse or Field Jacket Overcoat		Additions to the Basic Uniform: Combat Suit, Overcoat, Gloves, and Wool Cap	
	5th	95th	5th	95th	5th	95th	5th	95th
Weight – in pounds	141.9	210.2	144.3	212.6	153.[illegible]	219.4	155.4	223.7
Body Dimension* – Inches								
A-1 Stature	67.8	75.8	67.8	75.8	67.8	75.8	67.9	75.9
B-1 Sitting Height	35.1	39.4	35.2	39.5	35.4	39.6	35.5	39.7
B-? Eye Height, Sitting	29.4	33.3	29.3	33.6	29.6	33.7	29.7	33.8
D-2 Shoulder Height, Sitting	21.4	25.3	21.8	25.7	22.2	26.0	22.2	26.0
D-8 Knee Height, Sitting	21.4	24.6	21.4	24.6	21.5	24.7	21.5	24.7
D-6 Buttock-Knee Length	21.9	25.4	22.0	25.5	22.1	25.6	22.3	25.8
D-3 Shoulder-Elbow Length	13.3	15.5	13.7	15.9	14.1	16.3	14.1	16.3
E-1 Shoulder Breadth	16.7	19.6	17.4	20.3	17.9	20.9	18.0	20.9
C-1 Chest Breadth	11.0	13.6	11.1	13.7	11.3	13.9	11.5	14.1
E-2 Elbow Breadth	15.7	20.4	16.2	20.8	17.0	21.6	17.3	21.9
C-3 Hip Breadth	12.6	15.0	12.8	15.2	13.2	15.5	13.5	15.2
E-? Hip Breadth, Sitting	13.2	16.0	13.4	16.2	13.8	16.5	14.1	16.8
E-? [illegible] Breadth ([illegible])	7.5	9.3	7.6	9.3	7.9	9.5	8.8	10.5
B-? Chest Depth	8.4	10.8	8.9	11.4	9.8	12.2	9.8	12.2
L-6 Foot Length	11.0	12.7	11.0	12.7	11.0	12.7	11.0	12.7
L-4 Foot Breadth	4.0	4.5	4.0	4.5	4.0	4.5	4.0	4.5
K-7 Hand Length	See Figure 4 Dimensions of the Gloved Hand							
K-10 Hand Breadth	See Figure 4 Dimensions of the Gloved Hand							

* The letter and number associated with the particular body dimension refers to the drawings of Figure 1.

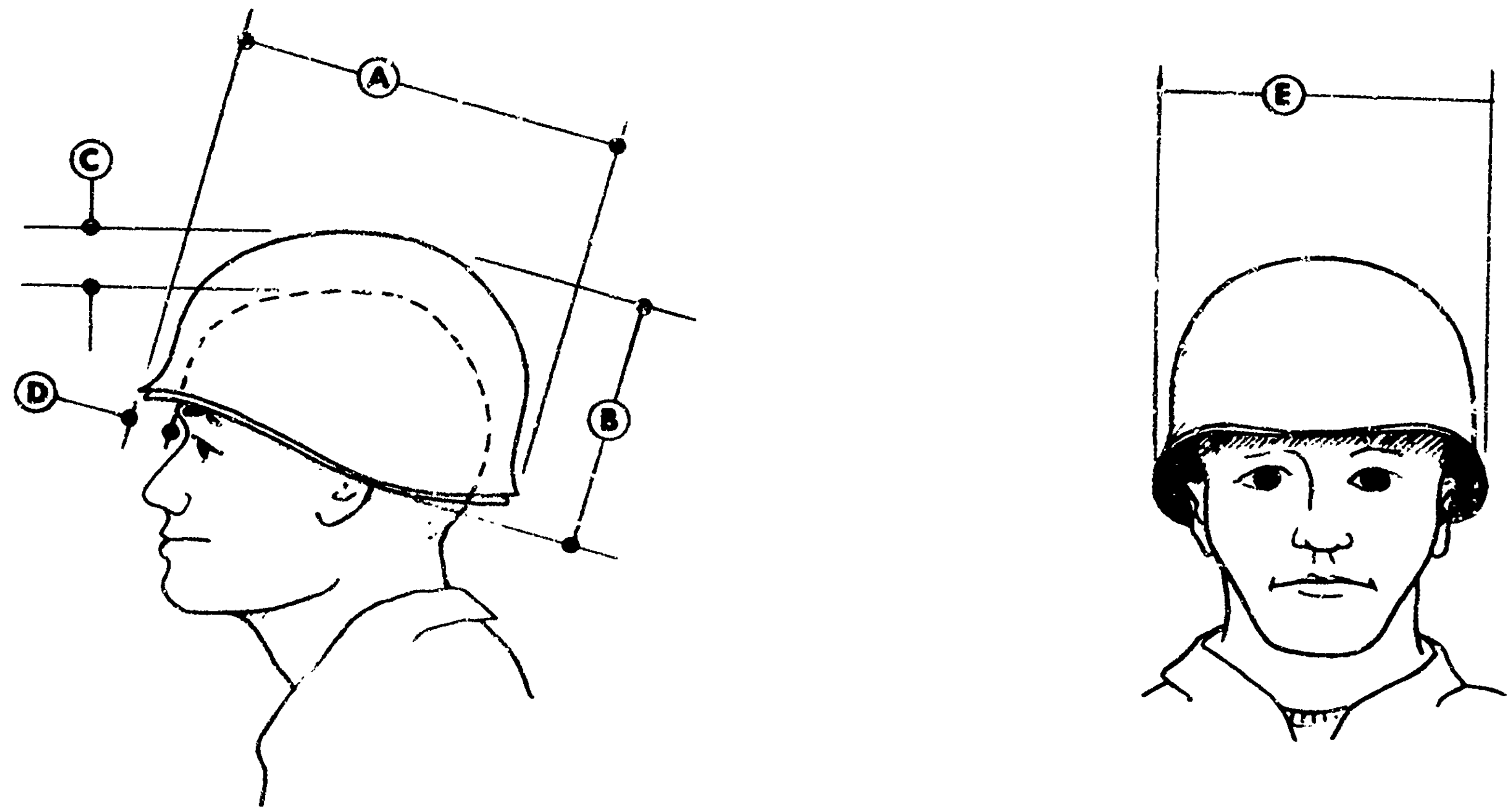


Fig. 2. M-1 Helmet

TABLE 3

Dimensions of the M-1 Helmet

A. Length, front rim to rear rim	Max	11"
B. Height, at maximum angle		6 7/8"
C. Top of head to top of helmet	Max	2"
D. Eyebrow ridge to front rim	Max	2"
E. Width, rim to rim	Max	9 1/4"

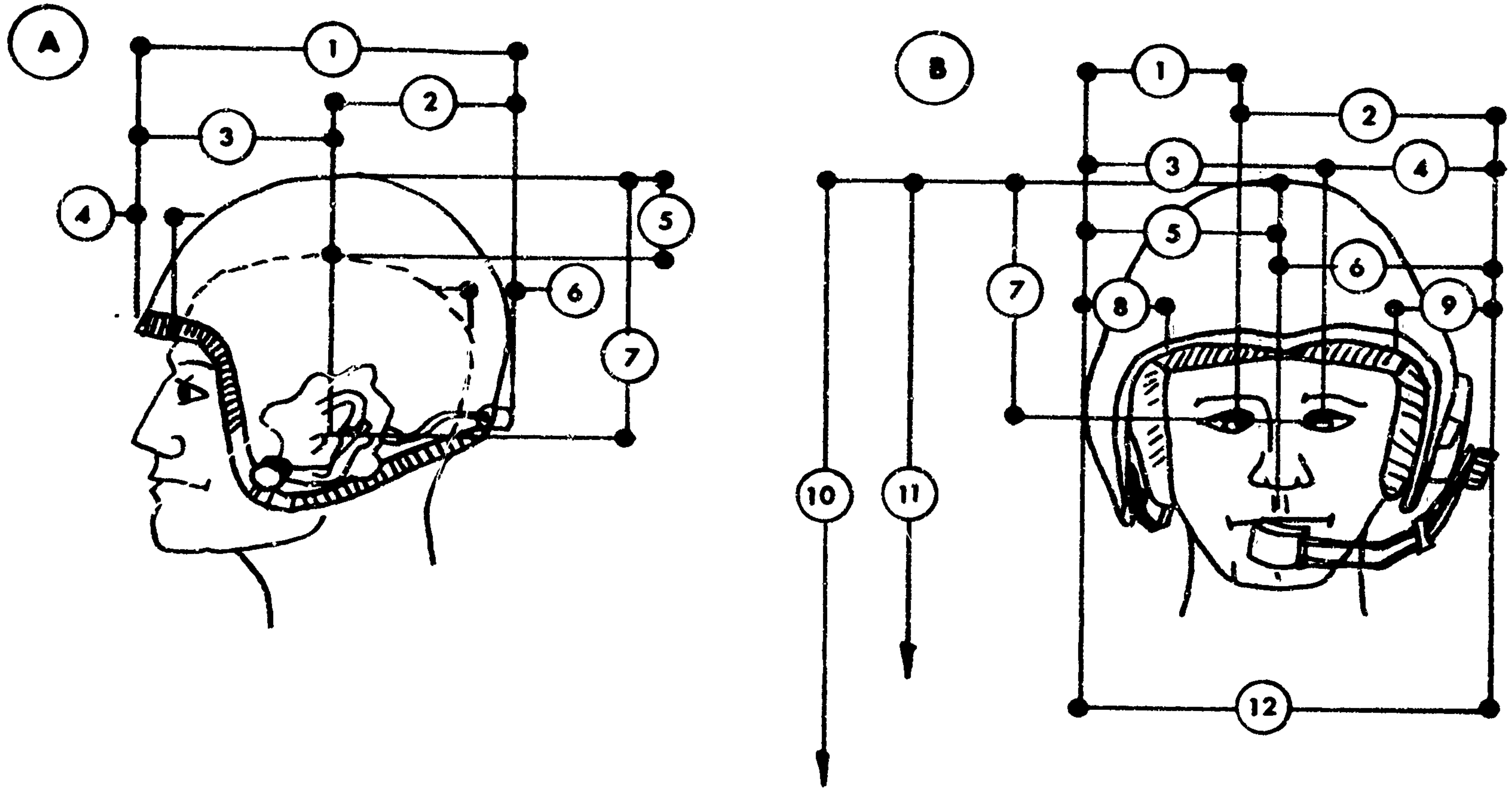


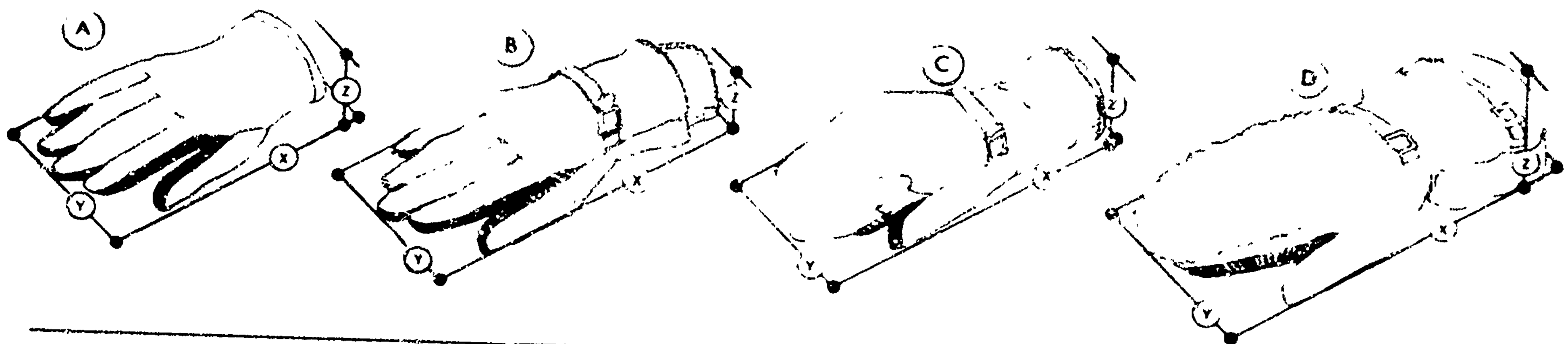
Fig. 3. CVC Helmet (T 56-6) Dimensions

TABLE 4

DIMENSIONS OF COMBAT VEHICLE CREWMAN HELMET (T 56-6) OVER BARE HEAD DIMENSIONS

Dimension (Inches)	Design Values (Percentiles) Bare Headed 5th	Bare Headed 95th	With Helmet 5th	With Helmet 95th	Added by Helmet 5th	Added by Helmet 95th
A						
1. Length of Head	7.3	8.3	10.5	11.0	---	---
2. Ear Hole to Back of Head	3.5	4.5	5.0	5.3	---	---
3. Ear Hole to Front of Head	3.5	3.8	5.5	5.7	---	---
4. Front Extension Beyond Head	---	---	----	----	1.7	1.9
5. Top Extension Beyond Head	---	---	----	----	2.1	2.1
6. Back Extension Beyond Head	---	---	5.0	5.3	1.5	0.8
7. Ear Hole to Top of Head	4.6	5.3	6.7	7.4	---	---
B						
1. Right Eye Pupil to Right Side Head	1.7	1.9	3.5	3.7	---	---
2. Right Eye Pupil to Left Side Head	4.0	4.6	7.0	7.6	---	---
3. Left Eye Pupil to Right Side Head	4.0	4.6	5.8	6.4	---	---
4. Left Eye Pupil to Left Side Head	1.7	1.9	4.7	4.9	---	---
5. Midline to Right Side Head	2.9	3.2	4.7	5.0	---	---
6. Midline to Left Side Head	2.9	3.2	5.9	6.2	---	---
7. Eye Height to Top Head	4.4	4.5	6.5	6.6	---	---
8. Right Extension Beyond Head	---	---	----	----	1.8	1.8
9. Left Extension Beyond Head	---	---	----	----	3.0	3.9
10. Standing Height (Nude) to Top Head	65.2	73.1	67.3	75.2	---	---
11. Sitting Height (Nude) to Top Head	33.8	38.0	35.9	40.1	---	---
12. Head Breadth	5.7	6.4	10.5	11.2	---	---

Note: Measurements are for a properly adjusted helmet.



Hand Altitude	A Anticontact Glove X	Y	Z	B Wet-Cold Glove X	Y	Z	C Wet-Cold Mitten X	Y	Z	D Arctic Mitten X	Y	Z
Extended flat:	10.3"	4.5"	2.5"	10.5"	5.5"	3.0"	14.0"	5.8"	3.2"	16.4"	5.2"	3.6"
Closed as fist:	7.0"	5.0"	3.3"	7.3"	5.8"	3.7"	11.5"	5.8"	3.8"	14.3"	5.2"	5.4"
Grasping handle:												
.25" diameter:	7.0"	5.0"	3.5"	7.3"	5.5"	3.5"	11.0"	5.7"	4.2"	14.0"	5.5"	4.5"
1.0" diameter:	7.0"	5.0"	3.5"	7.3"	5.3"	4.0"	11.0"	5.2"	4.5"	14.0"	5.2"	4.5"
2.0" diameter:	7.5"	4.5"	4.2"	8.0"	4.7"	4.0"	12.0"	5.2"	4.7"	15.0"	5.4"	5.0"
Grasping knob:												
.25" diameter	8.0"	3.8"	4.3"	9.0"	4.6"	4.0"	11.5"	5.0"	4.2"	15.5"	4.8"	4.5"
1.0" diameter	9.0"	3.5"	4.0"	9.0"	4.5"	4.0"	12.0"	5.0"	4.2"	15.8"	4.8"	4.8"
2.0" diameter	9.5"	3.7"	3.7"	9.2"	4.5"	4.2"	12.5"	4.6"	4.4"	16.0"	4.7"	4.8"

Fig. 4 Dimensions of Gloved Hand

Work Station Entrance and Exit

1. Routine - Entrances and exits should be provided for enclosed work areas to permit unrestricted flow for all anticipated traffic. They should be so located that using personnel will not accidently come into contact with equipment controls.

2. Non-routine - Consideration should be given for providing auxiliary entrances and to the requirement for emergency exits. Sufficient space should be allowed for rapid exit of all occupants, including those who may be required to wear bulky protective clothing or who may be carrying essential items of equipment, without risk of injury to personnel or damage to equipment being carried.

3. Stairs, ladders, and ramps should be:

a. Provided at all locations where equipment design or maintenance actions require personnel to abruptly change elevation by more than 12 inches.

b. Designed, installed, or provided to effect the most immediate and efficient access to and between work places and areas.

c. Constructed of materials which are lightweight, non-conductive, splinterproof, waterproof, humidity resistant, and resistant to chemical action.

d. Made strong enough to withstand the combined weight, using 250 pounds per man, of the largest anticipated number of personnel and equipment to be on them at any one time.

e. Provided with nonskid surfaces on all areas where personnel are expected to step, walk or stand.

f. Cleared of obstructions, edges, notches, or burrs which could injure personnel or damage hoses and cables.

g. Adequately lighted (see pages 64-66).

h. Adequately marked against dangers involved in their use, e.g., against unavoidable low overhead, possible shock, etc.

i. Should be designed to be carried, handled, and positioned by one or not more than two men.

4. Stairs and ramps may also be used to provide safe and easy passage over low objects (pipes, lines, ridges, etc.).

5. The layout and design of stairs, ladders and ramps should consider:

   a. Limitations in the amount of space and clearance available.

   b. Expected environmental conditions, particularly whether the structure is likely to become wet or covered with ice or snow.

   c. The type, direction and frequency of traffic over the structure.

   d. The relative efficiency of alternative traffic plans and patterns.

   e. Loads or other encumberances to be carried by personnel.

   f. The configuration and weight of other equipments that may have to be moved over the route.

6. The primary basis for selection of stairs, ladders, and ramps is the angle of inclination of the structure as a function of the available space and structural constraints. Figure 5 shows the preferred and critical angles of incline suitable for these structures.

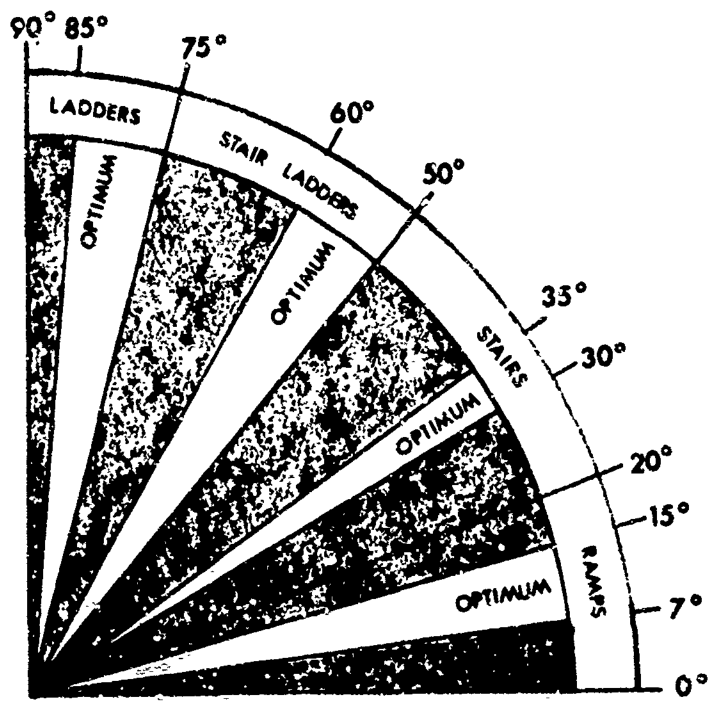


Fig. 5. Angles of Incline for the Use of Various Structures

Ladders

1. Stair Ladders are preferred to rung ladders; they provide better footing and faster, safer passage. However, both hands are required on the handrails for sure balance and fast movement; it is hazardous for personnel to carry loads up or down stair ladders. When stair ladders are used the clearance should be sufficient for one person only. If simultaneous two-way traffic is desired, separate UP and DOWN ladders should be provided. If these are located side by side, a double center handrail should be provided with a minimum of 6" between rails (8" recommended). For stair ladder dimensions see Figure 6.

2. Rung Ladders are not desirable for frequent passage. They are comparatively unsafe, difficult to climb, and difficult to work from. Only loads which are strapped to personnel can be carried up ladders safely. Fixed ladders are preferable to semi-permanent or movable ladders; the former are more stable, less subject to clearance problems, and can be affixed with guardrails, safety belt rigging and other safety features. For rung ladder dimensions see Figure 7.

3. Portable ladders should be provided only for emergency functions, infrequent maintenance tasks, or to satisfy tactical requirements which obviate use of permanent ladders.

4. When ladders are used between several floors, they should be offset and be provided with guarded landings at every floor. Guardrails should be provided at the top entrance to ladders, if the ladder well is open.

5. Ladder cages (see Fig. 7) should be provided for fixed ladders over 20 feet long, with the inside of the cage being clear of obstructions.

6. Round rungs provide better hand holds, but level steps, 3-4" wide, may be used if handrails are provided on both sides of the ladder.

7. Rubber cleated, pivoted feet should be provided on ladders for use in non-freezing weather, and steel cleats for use in ice or snow.

8. Hinges and locks should be used in preference to bolts and nuts for assembly of two-section extension ladders.

9. Safety devices on either fixed or portable ladders should be provided whenever length, use, or operating conditions require, e.g., provide pole lashing devices for ladders to be used against poles, or carrier rails and safety belts for long ladders to be used in adverse weather or under emergency conditions.

10. Catches and other mechanisms required for folding ladders should be simple, easy to release and maintain, even while wearing a Wet-Cold Mitten (see Fig. 4)

11. Where one man will be required to manually lift and store ladders, the lift distance from ground level and ladder weight should not exceed the following:

Lift Distance	Weight
5'	25 lbs
6'	20 lbs

		Min	Max
A.	Angle of rise:	50^{o}	75^{o}
B.	Tread depth:		
	For 50 rise:	6"	10"
	For 75 rise:	3"	5.5"
C.	Riser height:	7"	12"
D.	Height, step to landing:	6"	12"
E.	Width, handrail-handrail:	21"	24"
F.	Min.overhead clearance:	68"	--
G.	Height of handrail:	34"	37"
H.	Diameter of handrail:	1.25"	2"
I.	Min.hand clearance:	3"	--

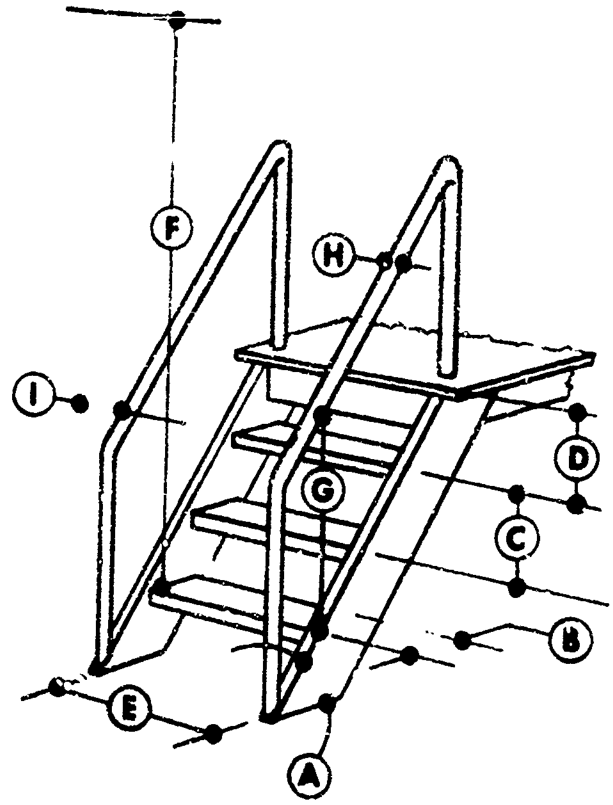


Fig 6. Stair Ladder Dimensions

A.	Height of cage from base of ladder:	7'
B.	Flare at bottom of cage:	32"
C.	Depth of cage from center of ladder:	28"
D.	Max.distance between cage ribs:	18"
E.	Width of cage:	27"
F.	Rung diameter: See fixed ladders	
G.	Rung spacing: See fixed ladders	
H.	Maximum ladder length:	
	Single section ladders:	30'
	Two-section metal ladders:	48'
	Two-section wood ladders:	60'
I.	Min.width between siderails:	
	Metal ladders:	12"
	Wood ladders:	
	Up to 10' long:	11.5"
	Add .25" for each additional 2' in length	

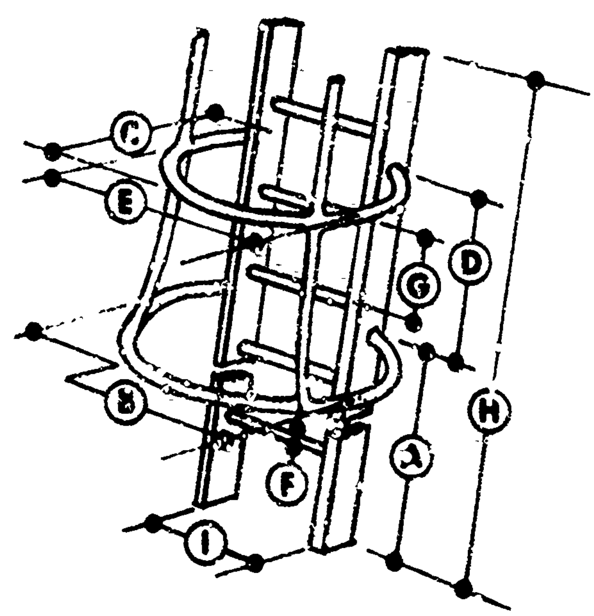


Fig 7. Rung Ladder and Ladder Cage Dimensions

A. Spread: 3.5" per ft length of front section plus 2.0" per ft length of back section
B. Tread depth: Min.3"; best 3-4"
C. Step spacing: Min.9"; best 11-12"
D. Min.width between top of siderails:
   Metal ladders: 12.0"
   Wood ladders: 11.4"
E. Width at bottom: Add 1" per foot of length
F. Length of ladder: Maximum of 20 ft

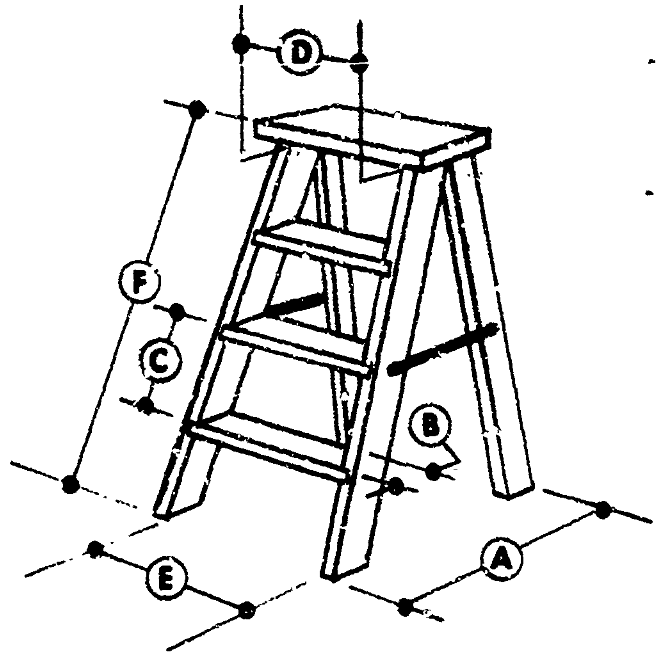


Fig 8. Step-Ladder Dimensions

	Min.	Max.
A. Angle of rise:	75°	90°
B. Rung or cleat diameter:		
Wood:	1.13"	1.5"
Protected metal:	.75"	1.5"
Metal that may rust:	1.0"	1.5"
C. Rung spacing:	9.0"	16.0"
D. Height, rung to landing:	6.0"	16.0"
E. Width between stringers:	12.0"	--
F. Climbing clearance width:	24.0"	--
G. Min.clearance depth:		
In back of ladder:	6.0"	--
On climbing side: 36" for 76°, 30" for 90°		
H. Height of string above landing:	33.0"	--
I. Max height of climb:	--	10.0'

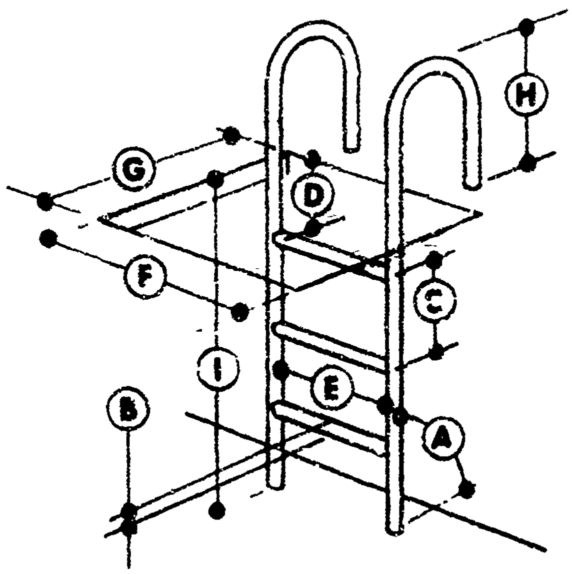


Fig 9. Fixed Ladder Dimensions

Stairs

1. The distance between steps or stairs (riser height) should be uniform, and the distance between steps and landings should not be less then 5 inches nor more than the uniform riser height. See Figure 10.

2. Long flights of stairs should be avoided. Landings are recommended every 10-12 treads and should be provided for every story (8-12 ft. elevation).

3. Where practical, treads should be open (without risers), however, metal screening (or kick plates) should be fastened to the underside where required to prevent injury to personnel or damage to equipment.

4. Deep treads (12") and low risers (5") should be used when loads over 20 pounds are to be carried or stairs are over two stories high.

	Min	Max
A. Angle of rise:	20°	50°
B. Tread depth:	9.5"	12"
C. Riser height:	5"	8"
D. Width (handrail to handrail)		
One-way stairs:	20"	--
Two-way stairs:	48"	--
E. Min. overhead clearance:	76"	--
F. Height of handrail:	30"	36"
G. Diameter of handrail:	1.25"	3.0"
H. Hand clearance:	1.75"	--

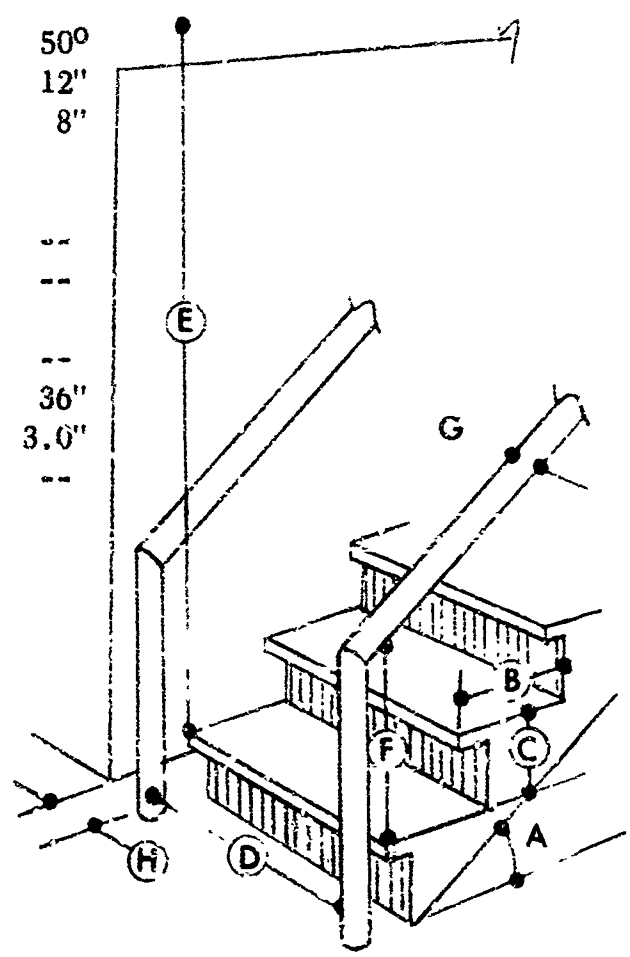


Fig. 10. Stair Dimensions

Ramps

1. Ramps or inclines should be used for slopes under 20^{o} (see Fig. 5). A combination ramp and stairway is preferred for slopes greater than 7^{o}.

2. Ramps are of value when rolling stock must be moved between different levels.

3. For pedestrian traffic, a stairway is more efficient from the standpoint of space, safety, and speed.

4. Ramps that are to be used for pedestrian traffic should be provided with a handrail.

5. Horizontal strips of non-skid material, at least 6 inches wide and spaced no more than 6 inches apart, should be applied to the entire ramp width.

6. Requirements for personnel to push or pull stock up ramps should be carefully evaluated in terms of human strength and safety.

		Min	Max
A.	Angle of rise:	--	20°
B.	Height of handrails:	38"	44"
C.	Width: Determined by function and usage. Particularly size of rolling stock and loads.		
D.	Diameter and handrail:	1"	3"
E.	Clearance around handrail:	2"	--

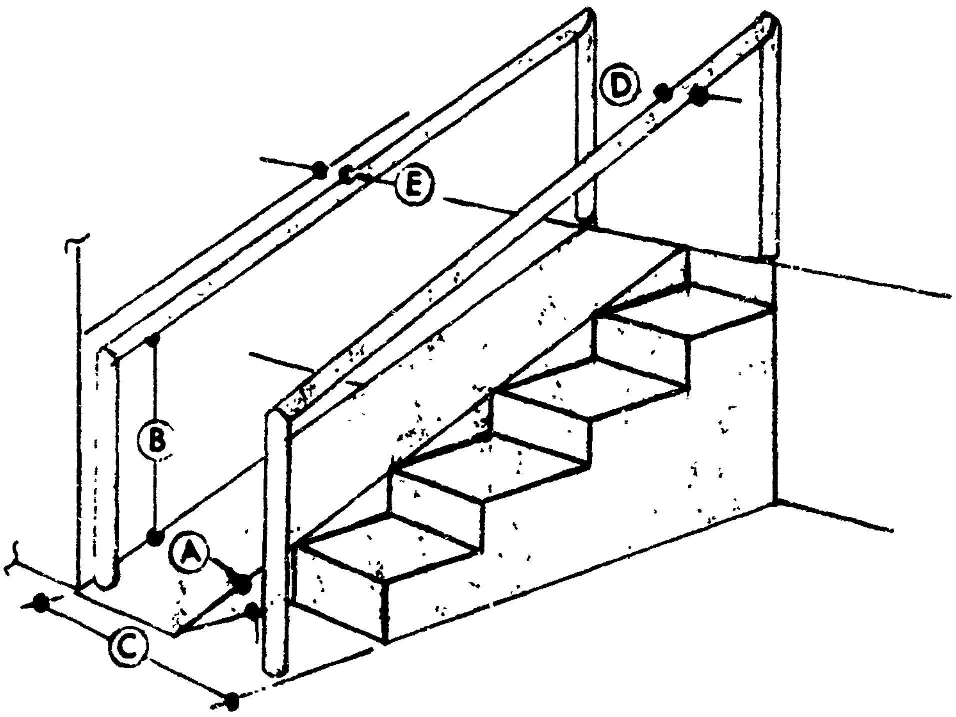


Fig. 11. Ramp Dimensions

Walkways and Passageways

1. Minimum lateral spacing requirements should be observed to allow unrestricted movement of personnel within the work area.

2. Consideration should be given to the maximum traffic load anticipated for any one time, direction of traffic flow, and the number and size of entrances and exits in the area.

3. Adequate clearance should be provided for personnel wearing bulky protective clothing and when carrying equipment. Although one man can pass through a corridor only 20 inches wide, a 30-inch width should be considered the minimum for a one-person or one-direction corridor.

4. A two-man or two-direction corridor should be 48-54 inches wide.

5. When a door opens into a walkway or passageway, additional lateral spacing is required, as shown in Figure 12.

6. Boundaries should be identified by prominent markings.

7. Non-skid surfaces should be provided.

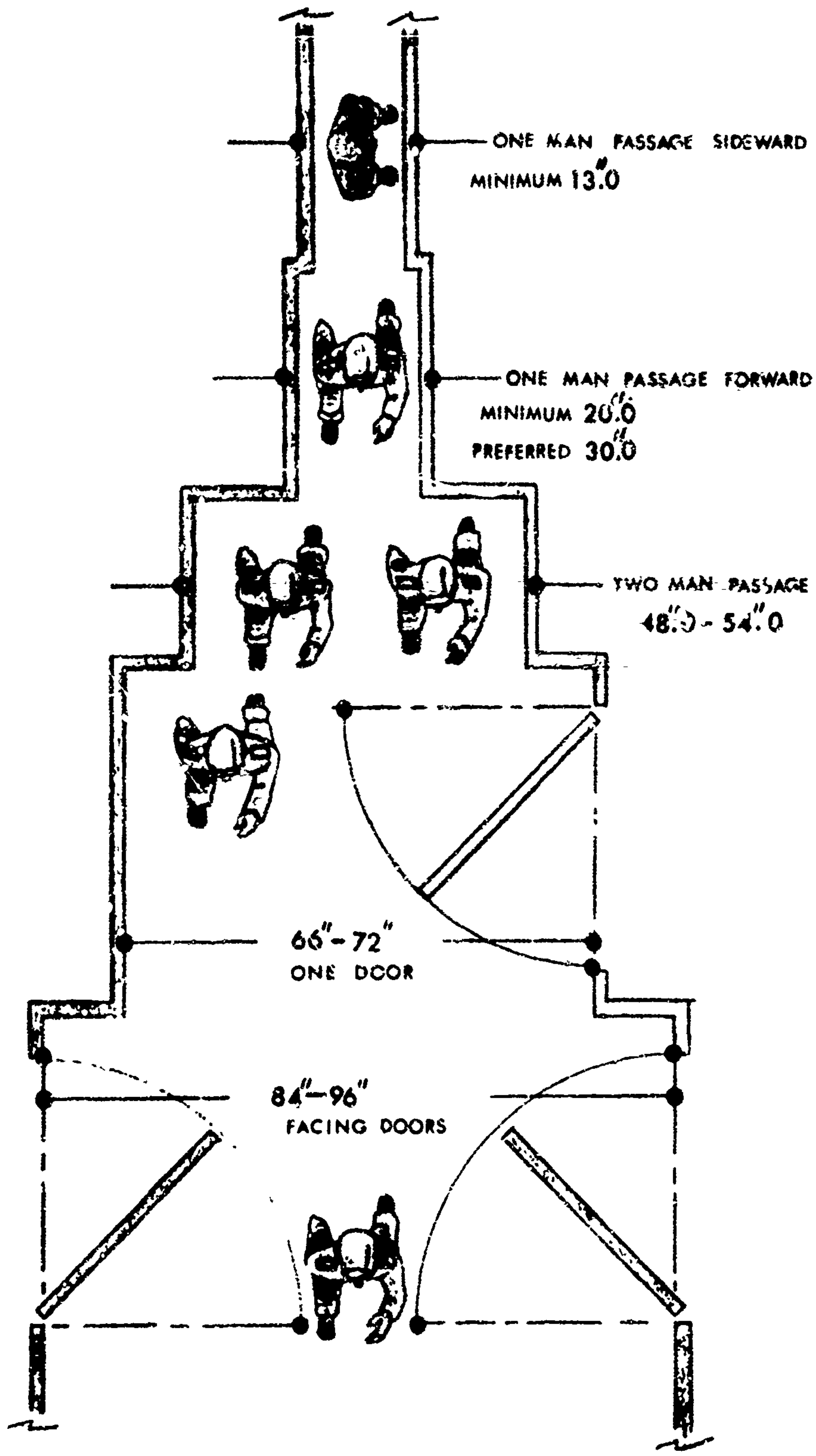


Fig. 12. Walkway and Passageway Dimensions

Doors

1. Doorsills are not recommended except where weather protection or special ventilation control is required.

2. Clearance of at least 4 inches (optimum 12 in.) between the door and wall is recommended.

3. Where large vehicles or large pieces of equipment have to be moved into and out of compartments, a sliding door is recommended.

4. When a sliding door is used, a separate hinged door in the sliding door should be provided for personnel use.

5. Vertical and sliding doors are useful for cramped spaces, but they are easily jammed when subject to blast, collision, etc.; therefore, they should never be installed as the only exit.

6. Door dimensions should follow those given in Figure 13.

Hatches

1. Dimensions for escape hatches will be dependent upon:

   a. The work area from which escape will be effected.

   b. Equipment and clothing personnel will be wearing.

   c. Environment which personnel will enter.

2. Wall hatches should be flush with the floor, where structural considerations will permit this arrangement (see Fig. 14).

3. It should be possible to open the hatch with a single motion of the hand or foot.

4. When a handle is used for opening the hatch, the force required should not exceed 30 pounds.

5. Emergency hatches placed in the overhead position should weigh no more than 50 pounds and be capable of operation by the 5th percentile man and should utilize the force of gravity in opening.

6. Ha[illegible] placed in the overhead position should require no more than 50 pounds force when a push operation is used for opening.

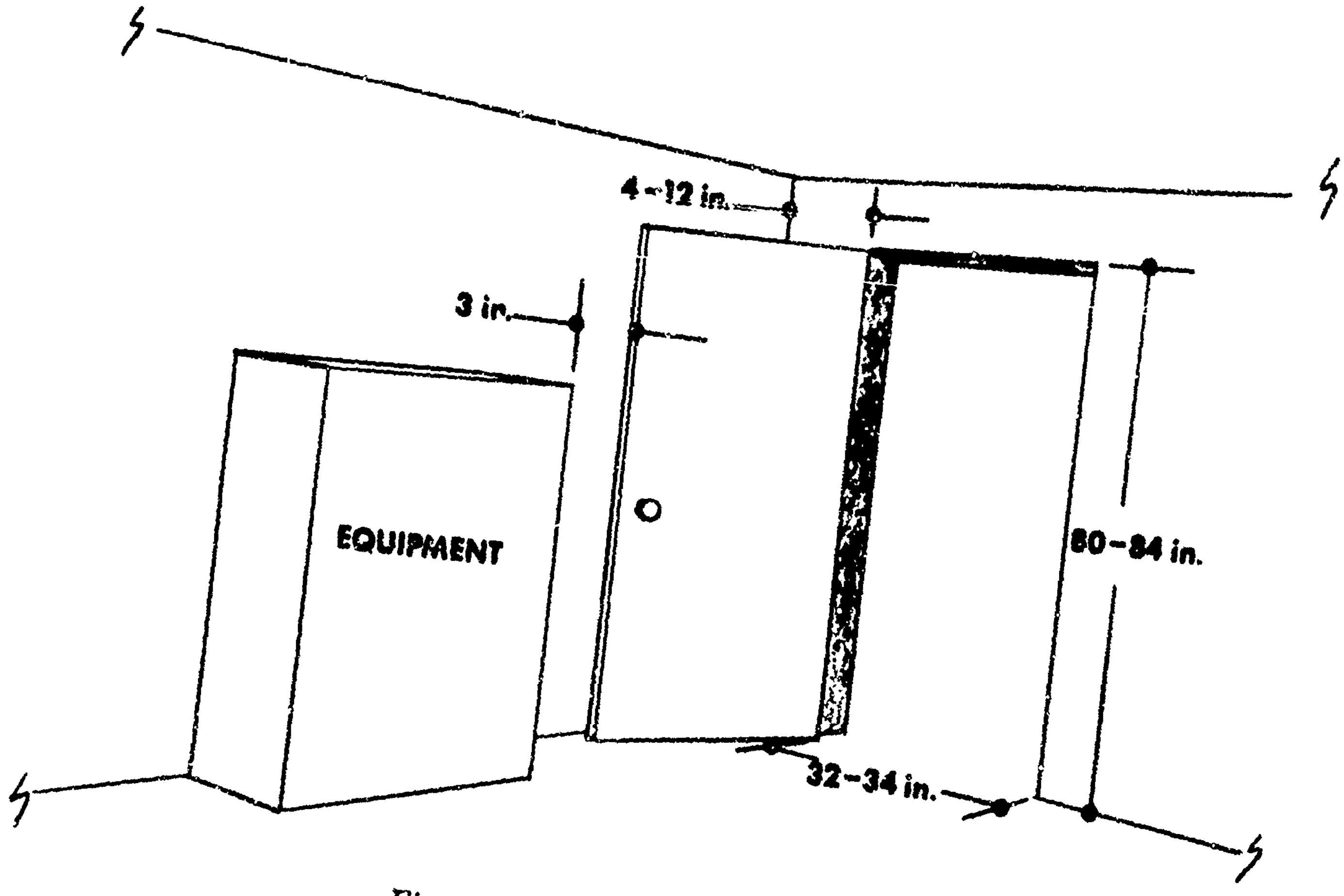


Fig. 13. Door Dimensions

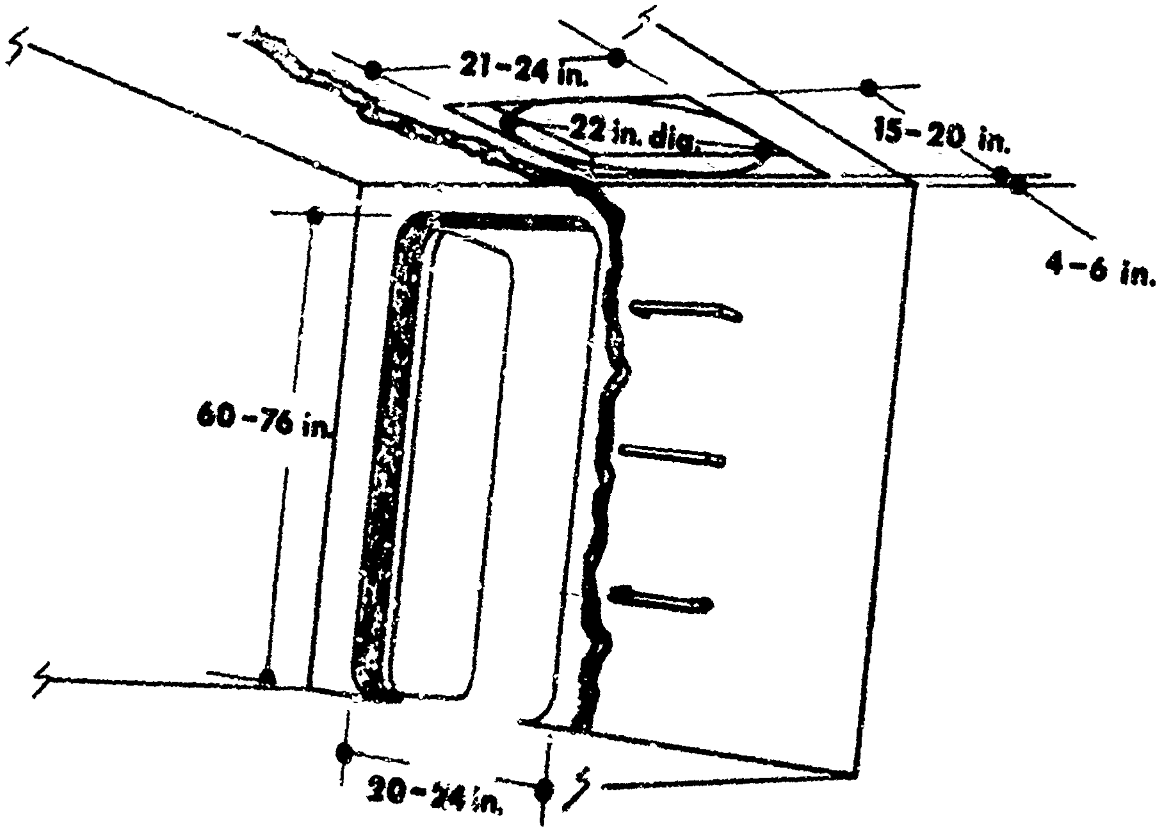


Fig. 14. Hatch Dimensions

7. Dimension of hatches used in emergency entrance and exit should be as follows: (See Fig. 14)

	Min.	Preferred
A. Rectangular hatch opening	15"x21"	20"x24"
B. Square hatch opening	18"	22"
C. Circular hatch opening	22"	24"

Platforms

1. Platforms should be provided as necessary to bring personnel within optimal, or at least tolerable working distance of equipment and features requiring, or related to, equipment operation. They should be designed to:

a. Be a minimum of 2 feet wide and 3 feet long.

b. Permit personnel to have both hands free for work.

c. Provide a continuing work surface around or between related portions of the work area.

d. Allow accomplishment of required adjustments by no more than two men in minimal time.

e. Have a capacity in excess of the heaviest combination of men and equipments to be supported at any one time. 250 pounds per man should be used to calculate load.

f. Conform closely to the shape of the equipment surface:

(1) General conformation should be within 2 inches.

(2) Gaps greater than 6 inches are objectionable.

(3) Contact plates, cushions, bumpers, or pads should be provided as necessary to protect equipment surfaces.

2. Wheel locks or brakes should be provided for platforms on wheels.

3. Portable platforms should be fully collapsible and constructed of lightweight material.

4. Provisions should be made for resting test equipment at convenient operating level.

5. When equipment is to be carried up onto a platform, access stairs should have an angle of climb preferably no greater than 35° inclination.

6. Handrails or grips should be provided.

Guardrails

1. Guardrails should be provided on all sides of platforms. At least two railings are recommended to ensure safe work areas. Guardrails and handrails should be provided as necessary to:

a. Prevent personnel from falling from elevated work places.

b. Prevent personnel from falling through floor openings, manholes, etc.

c. Keep personnel within bounds while passing through hazardous areas.

d. Assist personnel in climbing inclines, stairs, etc.

e. Assist personnel in traversing or working in moving vehicles or in areas subject to high winds, fog, ice, or other hazards.

2. The construction of guardrails and handrails should:

a. Satisfy the requirements of Figure 15.

b. Be supplemented with screening or latticework.

Seated Work Space

1. The main objective in seat design is to provide some body stabilization so the operator can best carry out his task.

2. Cushioned chairs should be provided whenever personnel are required to perform in the sitting position for more than one hour at a time or more than 20% of the time and should be cushioned (see Fig. 17 and Table 5). Stools or benches will suffice for other sitting operations and should conform to the requirements for seats where applicable.

3. A good seat should be designed so that the cushioned areas:

a. Are flat and firm, but soft enough to allow limited deformation.

b. Provide shock-absorber effect by resilient material under the cushion.

c. Support body weight primarily on the two bony points of the pelvis.

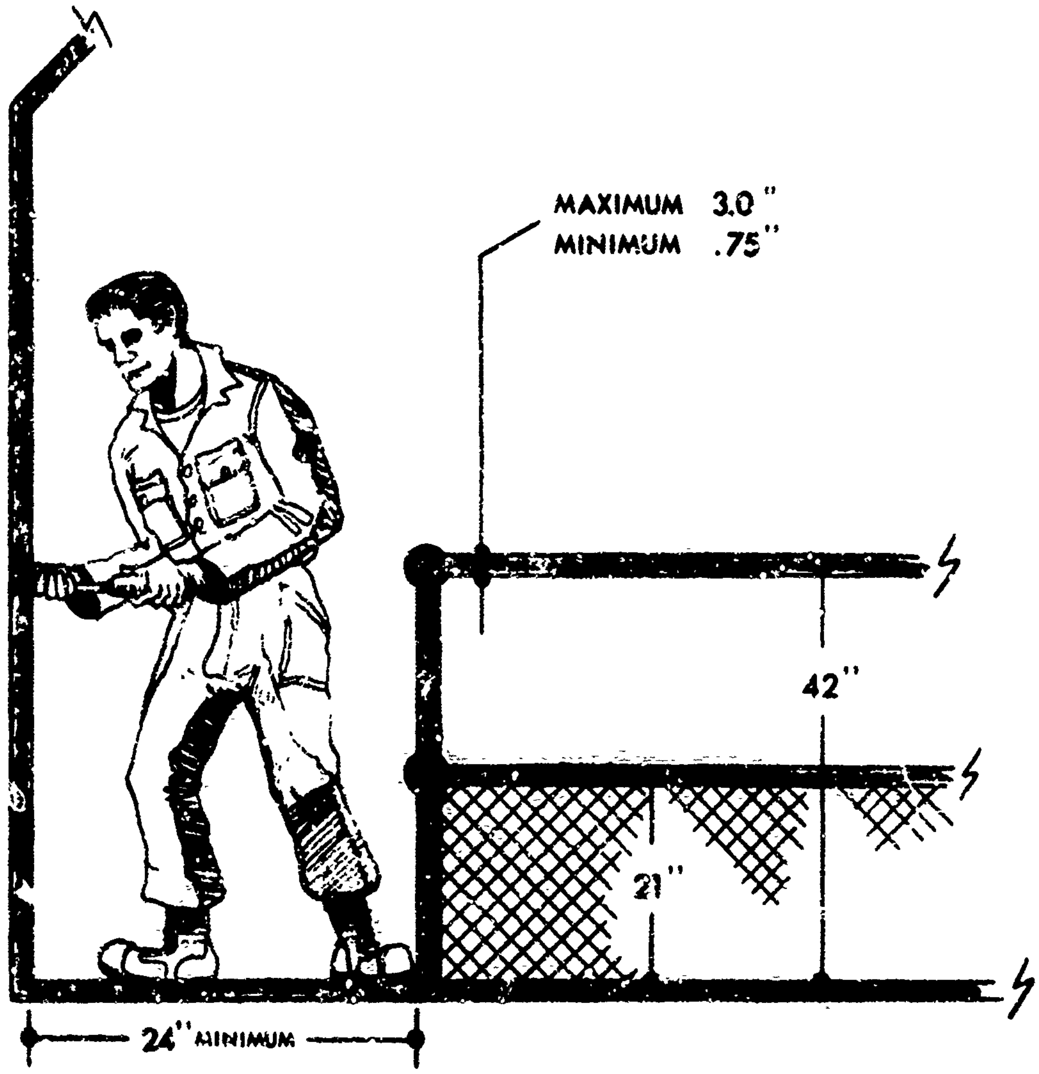


Fig. 15. Guardrail and Handrail Dimensions

d. Are tilted backwards 5-7 degrees to allow seat rather than muscles to support the back.

e. Follow inward curve of the lower back to relieve back muscles.

f. Provide adequate support for the lumbar region of the spine (lower or small of the back) since this is the area of the back subject to greatest strain.

g. Does not place pressure under the thighs.

h. Are perforated or ventilated to prevent "hotness" or "sweatiness."

i. Allow sitter to shift positions keeping in mind that the more support area provided by a backrest, the greater the ability to alter one's positions.

4. Arm rests should be provided to help elbows support some of the upper body weight; these should be removable and undercut for hips and thighs. Where a console or panel has a tracking control, the operator's arms should be supported so they lie in the same plane as the control.

5. Footrests should be provided wherever seat height exceeds 18 inches, work surface height exceeds 30 inches, and where there are extended periods of operation.

6. Some of the advantages of the seated position include:

a. Simultaneous operation of pedal controls.

b. Greater mechanical advantage available for foot-operated controls.

c. Reduction of fatigue.

d. Increased stability and equilibrium of operators whose equipment is subject to vibration and other motion.

7. Where space constraints preclude the use of a permanent seat, consideration should be given to the use of a temporary "swing-away" seat (see Fig. 16).

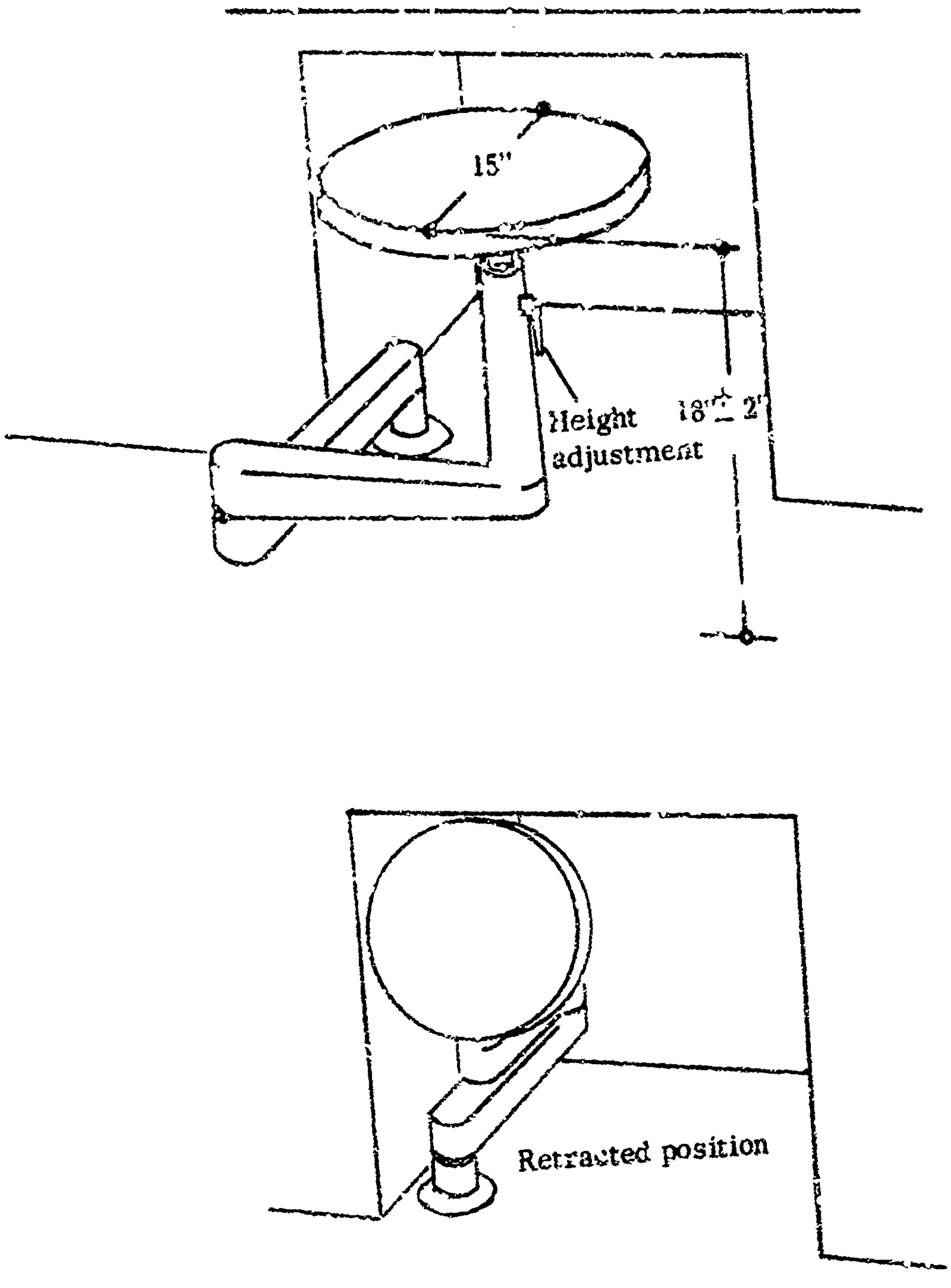


Fig. 16. Swing-away Seat for Short-term Operations

TABLE 5

SEATED WORK SPACE DIMENSIONS

	Fixed	Adjust*
Chair Dimensions:		
Arm Rests:		
A. Length	10"	
B. Width	2"	
C. Height	8.5"	
D. Separation	18"	
Seat:		
E. Width	16"	
F. Height	18"	± 2"
G. Depth	16"	
Back Rest:		
H. Space	6"	± 2"
I. Height	15"	
J. Width	16"	
Footrests:		
L. From Center	7"	
M. Width	6"	
N. Length	10"	
Work Surface Dimensions:	Min.	Best
O. Kneehole Depth	18"	--
P. Kneehole Width	20"	--
Q. Kneehole Height (Standard Office)	25"	--
R. Desk to Wall	32"	--
S. Table to Wall	24"	--
T. Lateral Work Clearance		
(1) Shoulders	23"	--
(2) Elbows	25"	--
(3) Best Over-All	40"	--
U. Height of Work Surface	29"	30"
V. Width of Work Surface		
(1) Elbow Rest Alone	4"	8"
(2) Writing Surface	12"	16"
(3) Desk Work Area		36"
W. Length of Work Area	30"	--

*Adjustment range. Adjustability is preferred for these dimensions.

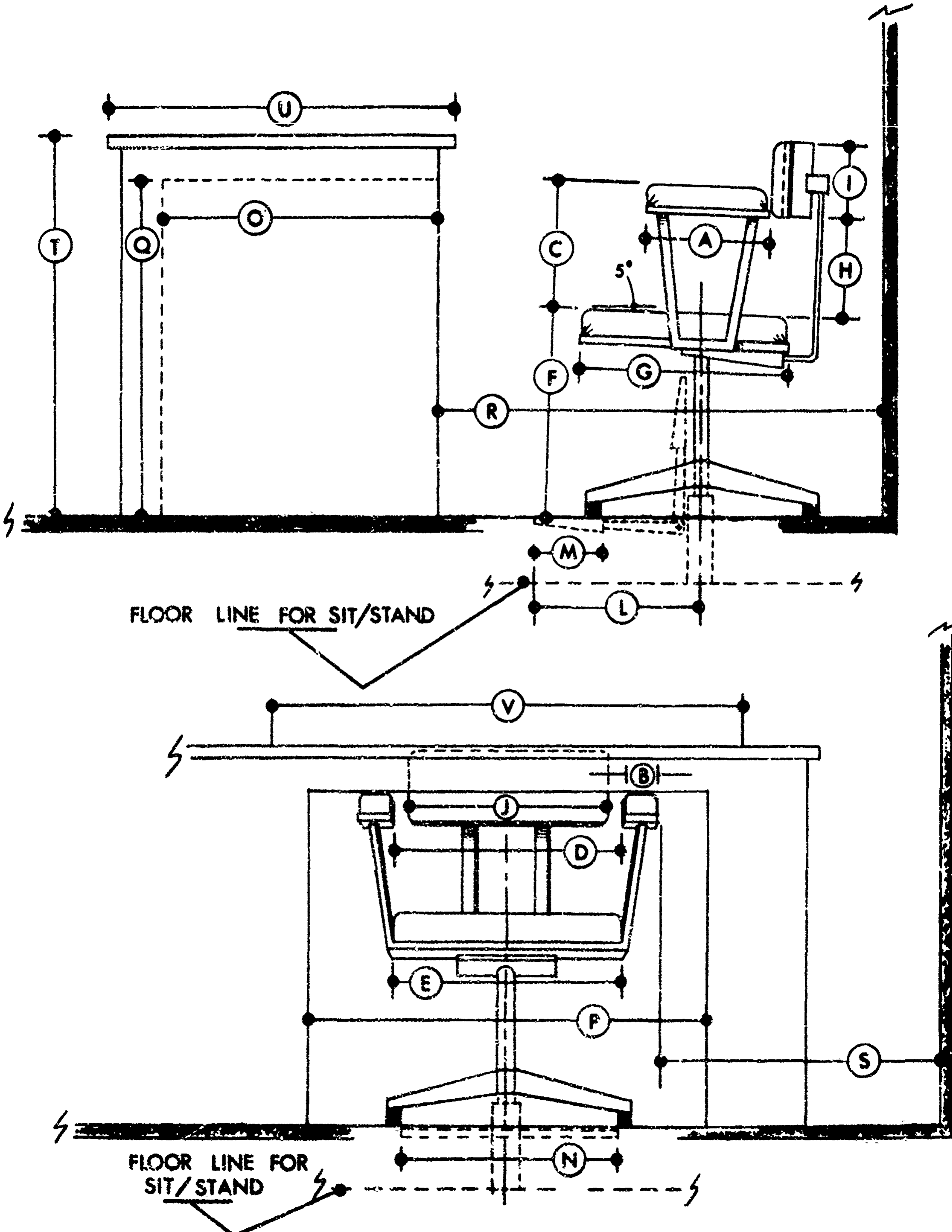


Fig. 17. Seated Work Space Dimensions

Standing Work Space

1. Whenever possible, design should allow the performance of routine, frequent, or short term operation from a standing position.

2. The work station for a standing operator is not as subject to strict dimensional constraints as is that for a seated operator, because a standing operator can face in any direction equally well or can walk from one position to another. If he is not free to do so, the workplace should be so designed that the operator takes either a seated or a sit-stand position.

3. Some of the advantages of the standing position include:

   a. An increase in ability to apply large muscular forces and effect greater control movements such as those required by a large lever.

   b. Access to visual and manual areas inaccessible from a stationary position, since there is greater freedom to move around the equipment.

   c. The operator has an alternative position; since many standing tasks may be performed in either a sit or stand position, such posture shifts tend to reduce fatigue and boredom.

   d. Conservation of space, since no provision need be made for knee room, and flat working surfaces may be used.

4. As long as constant attention in one particular direction is not required, equipment that involves only occasional viewing or manipulation can be placed, at the proper height, anywhere around the operator. Illustrated in Figure 18 and Table 6 are the recommended dimensions for the man-equipment relationship while the operator is in the standing position.

Mobile Work Space

1. Many times when personnel are accomplishing their tasks it becomes necessary for them to perform functions in neither a sitting nor standing position due to space limitations. When personnel are required to work in or pass through these limited spaces, the appropriate values should be selected from those provided in Figure 19 and Table 7.

Human Range of Motion

1. All operating positions should allow freedom to move the trunk of the body. When large forces (in excess of 30 pounds) or large control displacements (in excess of 15 inches in a fore-aft direction) are required, the operator should be provided with sufficient space to move his entire body.

2. Expressed in Table 8 are the ranges, in angular degrees, for each type of voluntary movement possible at the joints of the body illustrated in Figure 20. The designer must keep in mind that these dimensions are high; since they are for nude personnel, they do not allow for the restrictions imposed by clothing.

3. The following general index will apply for the use of the dimensions in Table 8.

   a. Lower Limit: If it is used as a direct function in the operation or maintenance of the equipment.

   b. Upper Limit: If it is used in the design for freedom of movement.

TABLE 6

STANDING WORK SPACE DIMENSIONS

Work Benches

Standard Type

A_1 Height: 36" above floor.

B_1 Width: 39" maximum.

Podium Type

A_2 Height: 41" above floor.

B_2 Width: 36" maximum.

Work Clearances	Min.	Best	Arctic
C. Passing body depth:	13"	15"	15"
D. Standing space	30"	36"	
E. Foot space	4" x 4"		
F. Overhead clearance	73"	80"	76"
G. Maximum overhead reach		76"	73"
H. Maximum depth of reach		23"	23"
I. Walking space width	12"	15"	15"
J. Passing body width	20"	32"	32"

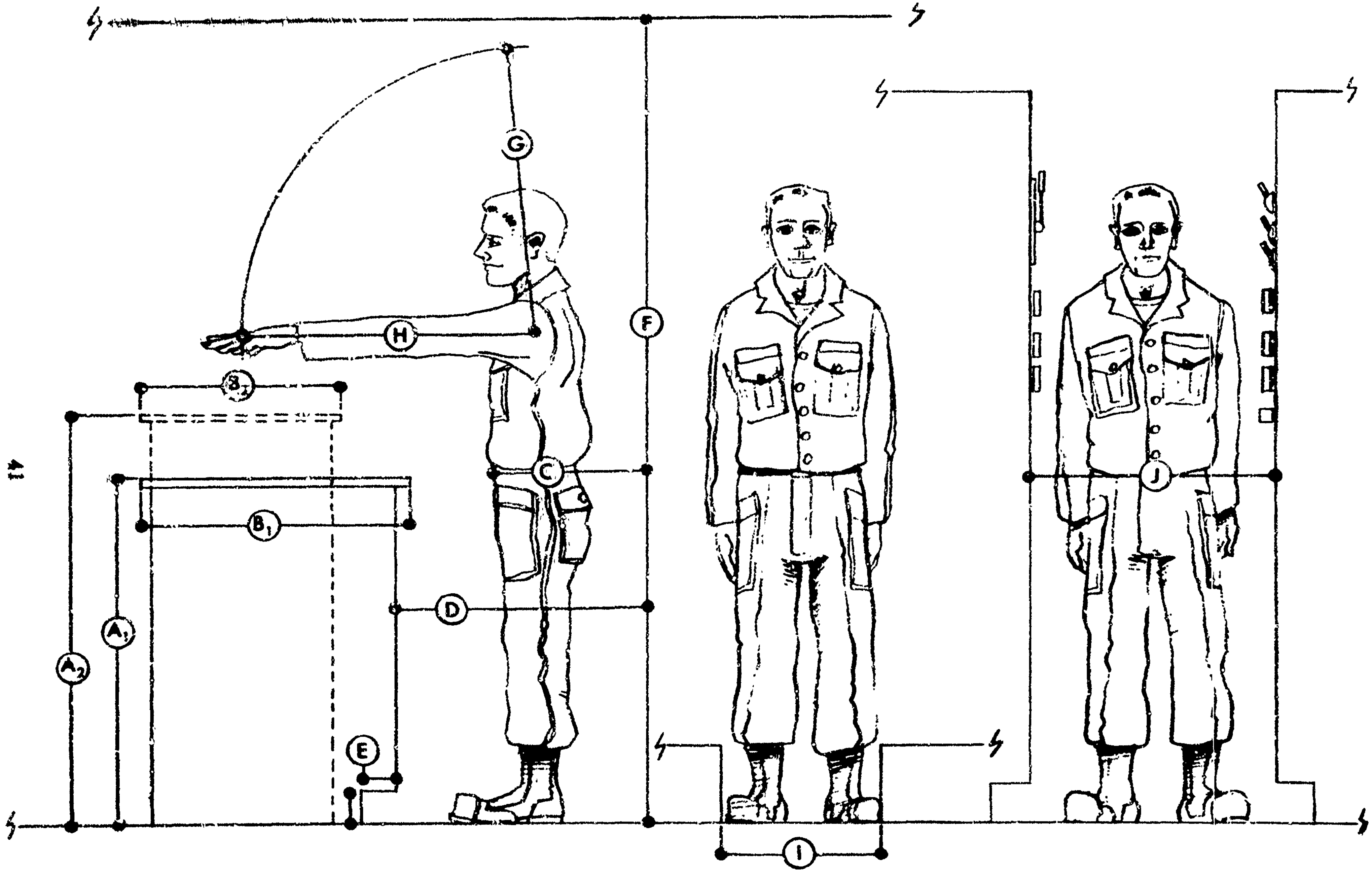


Fig. 18. Standing Work Space Dimensions

TABLE 7
MOBILE WORK SPACE DIMENSIONS
(in inches)

	Minimum	Best	Wearing Arctic Clothing
A. Two men passing abreast:	42	54	60
B. Two men passing facing:	30	36	36
Catwalk Dimensions:			
C. Height:	63	73	75
D. Shoulder width:	22	24	32
E. Walking width:	12	18	18
F. Vertical entry hatch:			
Square:	18	22	32
Round:	22	24	
G. Horizontal entry hatch:			
1. Shoulder width:	21	24	32
2. Height:	15	20	24
H. Crawl through pipe:			
Round or square:	25	30	32
Supine work space:			
I. Height:	20	24	26
J. Length:	73	75	78
Squatting work space:			
K. Height:	48	--	51
L. Width:	27	36	40
Optimum display area:	27	43	
Opitum control area:	19	34	
Stooping work space:			
M. Width	26	40	44
Optimum display area:	32	48	
Optimum control area:	24	39	
Kneeling work space:			
N. Width:	42	48	50
O. Height	56	--	59
P. Optimum work point:	--	27	--
Optimum display area:	20	35	--
Optimum control area:	20	35	
Kneeling crawl space:			
Q. Height:	31	36	38
R. Length:	59	--	62
Prone work or crawl space:			
S. Height:	17	20	24
T. Length	96	--	--

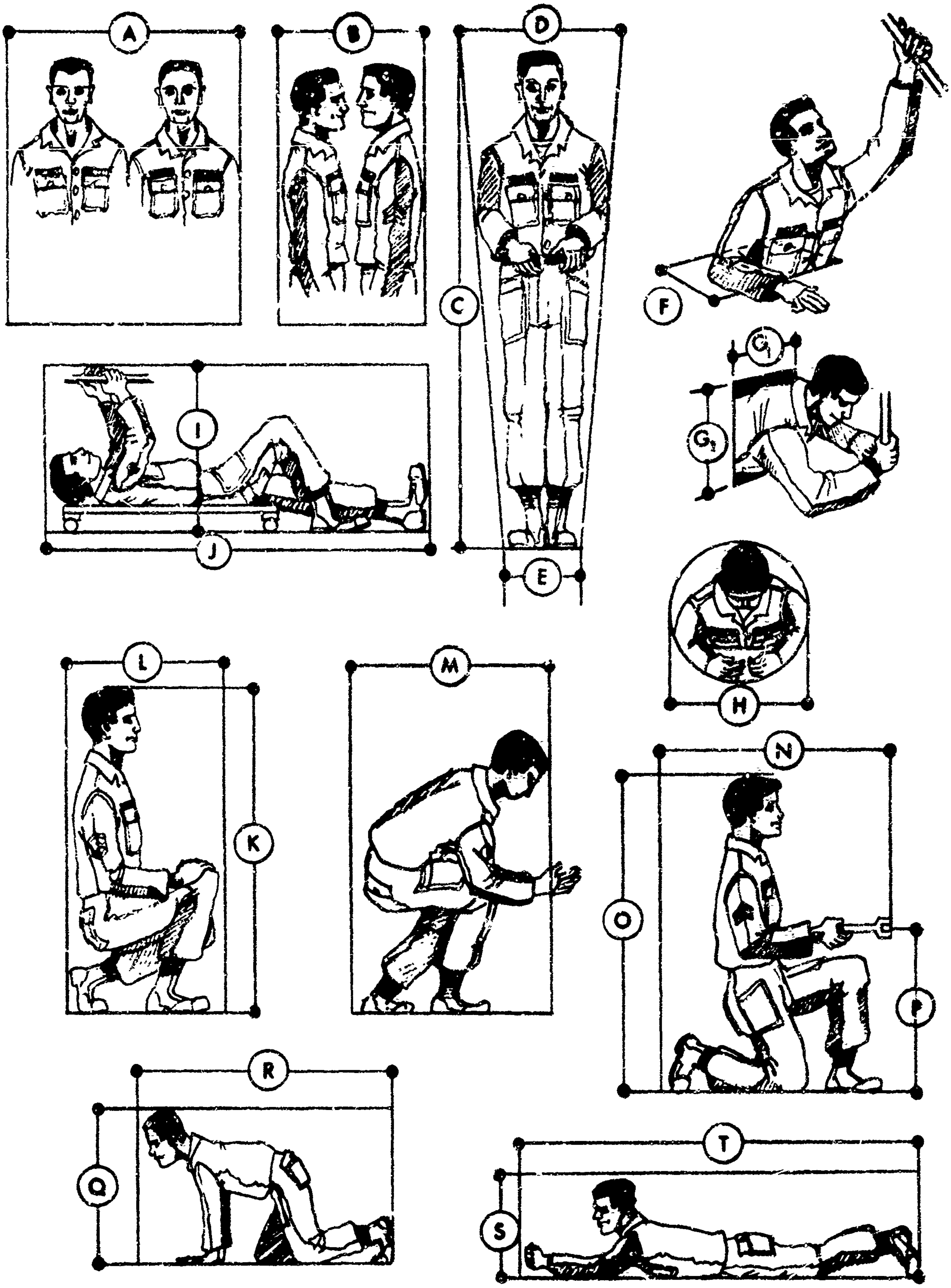


Fig. 19. Mobile Work Space Dimensions

TABLE 8

HUMAN RANGE OF MOTION*

Body Member and Movement	Lower Limit (degrees)	Upper Limit (degrees)	Average (degrees)
A. Wrist			
1. Flexion	78	102	90
2. Extension	86	112	99
3. Abduction	40	54	47
4. Adduction	18	36	27
B. Forearm			
1. Supination	91	135	113
2. Pronation	53	101	77
C. Elbow			
1. Flexion	132	152	142
D. Shoulder			
1. Lateral Rotation	21	47	34
2. Medial Rotation	75	119	97
3. Extension	47	75	61
4. Flexion	176	190	188
5. Adduction	39	57	48
6. Abduction	117	151	134
E. Hip			
1. Flexion	100	126	113
2. Adduction	19	43	31
3. Abduction	41	65	53
4. Medial Rotation (prone)	29	49	39
5. Lateral Rotation (prone)	24	44	34
6. Lateral Rotation (sitting)	21	39	30
7. Medial Rotation (sitting)	22	40	31
F. Knee Flexion			
1. Prone	115	135	125
2. Standing	100	126	113
3. Kneeling	150	168	159

*These dimensions are based on the nude body. The ranges are larger than can be expected when personnel are clothed.

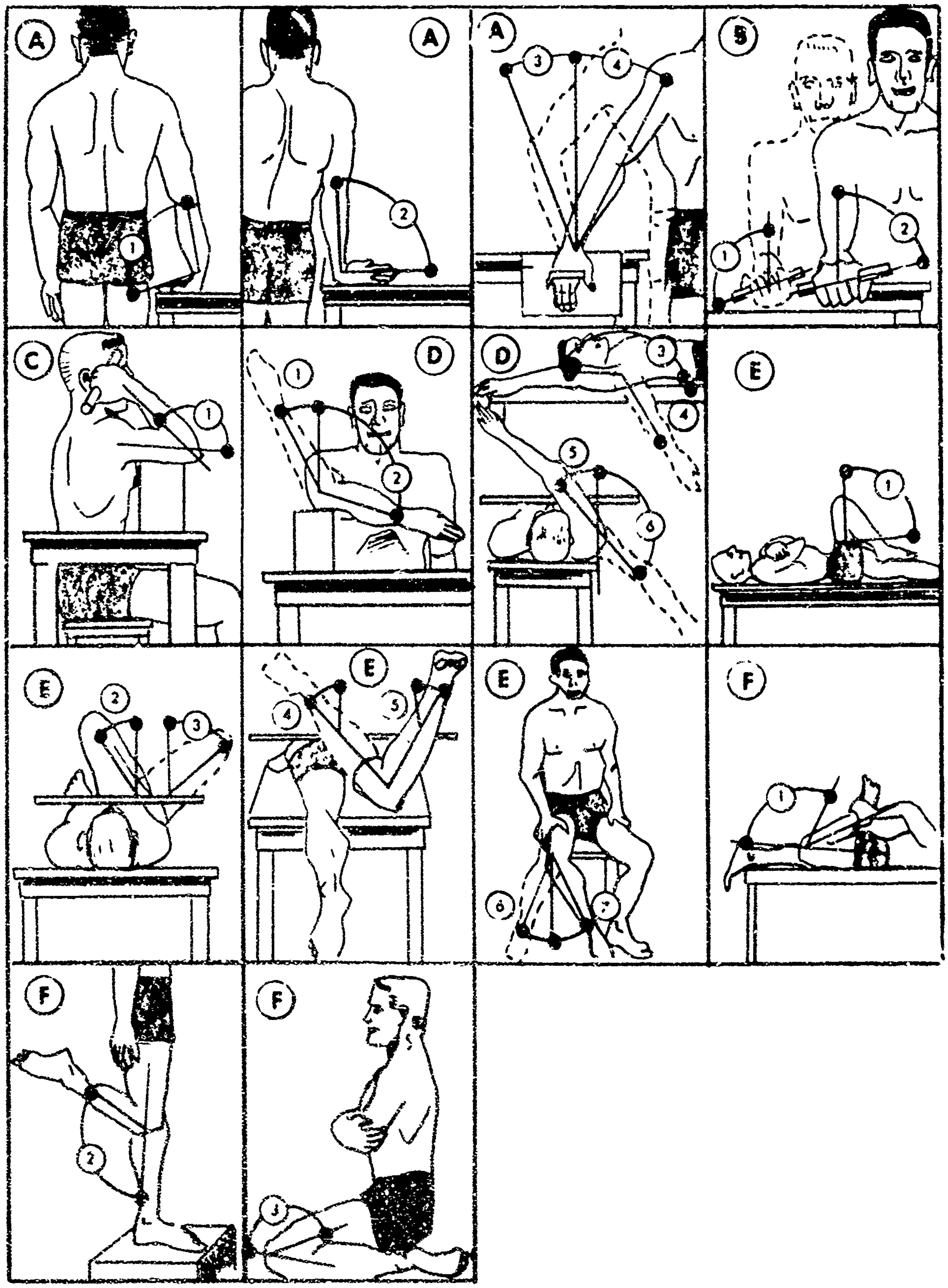


Fig. 20. Human Range of Motion

TABLE 8 Continued*

Body Member and Movement	Lower Limit (degrees)	Upper Limit (degrees)	Average (degrees)
G. Foot Rotation			
1. Medial	23	47	35
2. Lateral	31	55	43
H. Ankle			
1. Extension	26	50	38
2. Flexion	28	42	35
3. Abduction	16	30	23
4. Adduction	15	33	24
I. Grip Angle	95	109	102
J. Neck Flexion			
1. Dorsal (back)	44	88	61
2. Ventral (forward)	48	72	60
3. Right	34	48	41
4. Left	34	48	41
K. Neck Rotation			
1. Right	65	93	[illegible]
2. Left	65	93	79

Flexion: Bending, or decreasing the angle between the parts of the body.
Extension: Straightening, or increasing the angle between parts of the body.
Adduction: Moving toward the midline of the body.
Abduction: Moving away from the midline of the body.
Medial Rotation: Turning toward the midplane of the body.
Lateral Rotation: Turning away from the midplane of the body.
Pronation: Rotating the palm of the hand downward.
Supination: Rotating the palm of the hand [illegible]

*These dimensions, based on nude body measurements, [illegible] than can be expected when personnel are clothed.

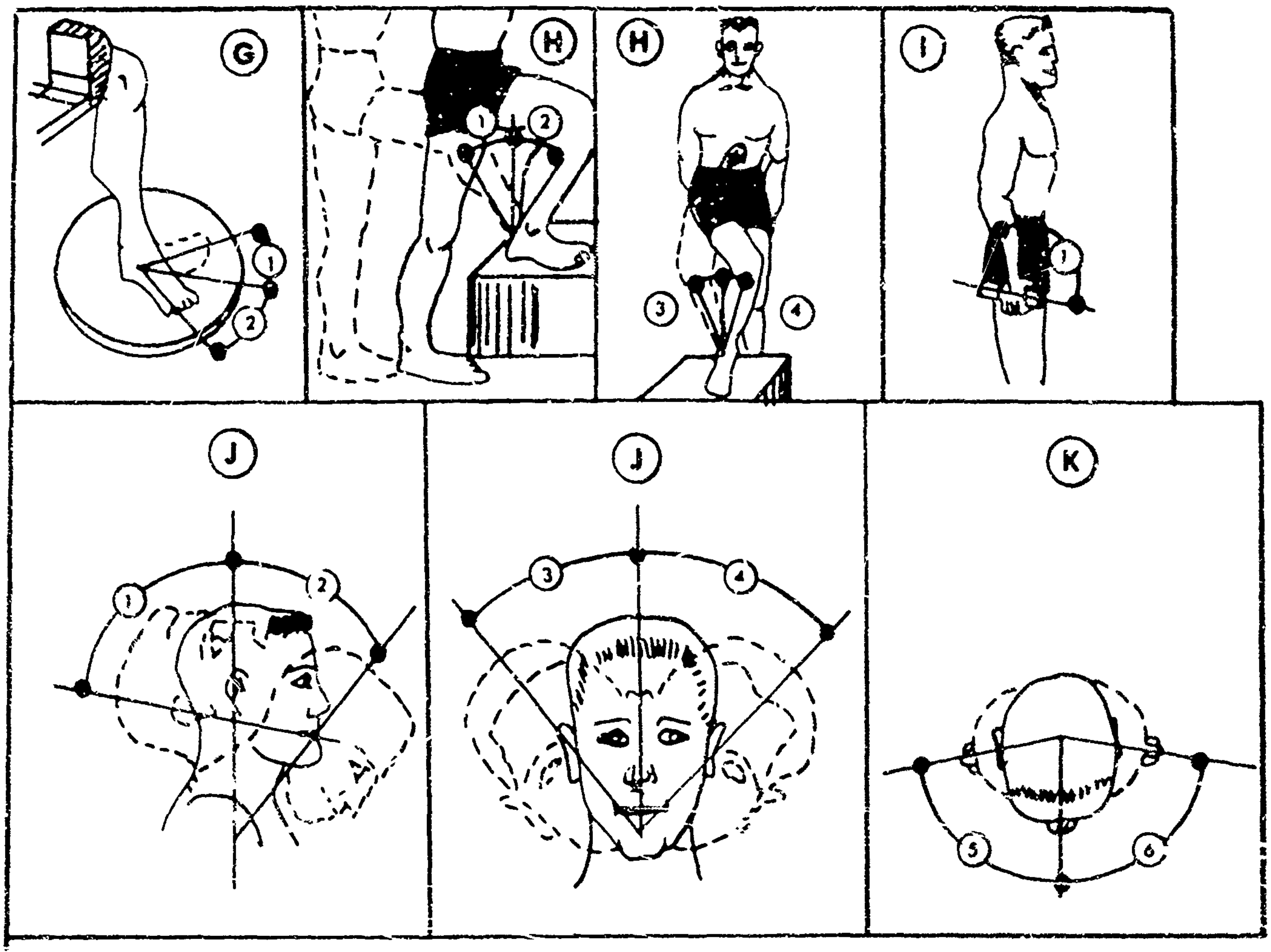


Fig. 20. Continued

Human Strength and Handling Capacity

1. The maximum amount of force or resistance that can be designed into a control should be determined by the greatest amount of force that can be exerted by the weakest person likely to operate the control. The maximum force that can be applied will depend on such factors as the type of control, the body member being used to operate the control, the position of this body member during control operation, the general position of the body, and whether or not support is provided by back rests, etc.

2. Equipment should be designed whenever possible to be lifted by one man. Two men may perform certain lifting tasks, but this is not normally desirable.

3. Lifting tasks should not require more than two men.

4. The approximate safe lifting capacity for 95 percent of the personnel is shown in Figure 21; however, the weight should be reduced considerably if:

   a. The object is very difficult to handle (e.g., bulky, slippery, etc.).

   b. Access and work space is less than optimum.

   c. The required force must be continuously exerted for more than one minute.

   d. The object must be finely positioned or delicately handled.

   e. The task must be repeated frequently (e.g., many times on a given day).

5. Listed in Figure 22 are the forces that can be exerted by 95 percent of the male personnel in terms of the direction of movement and the body member used.

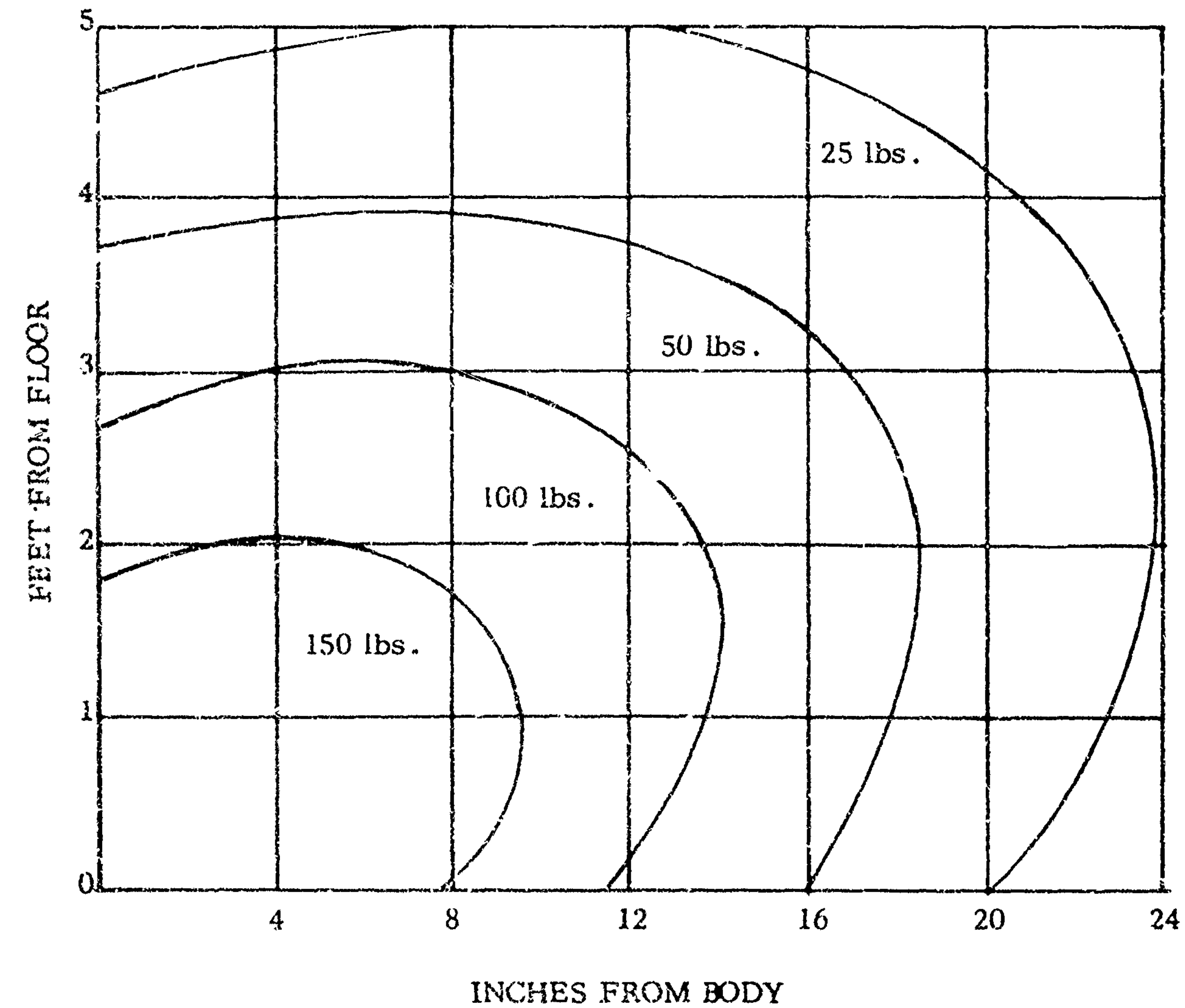
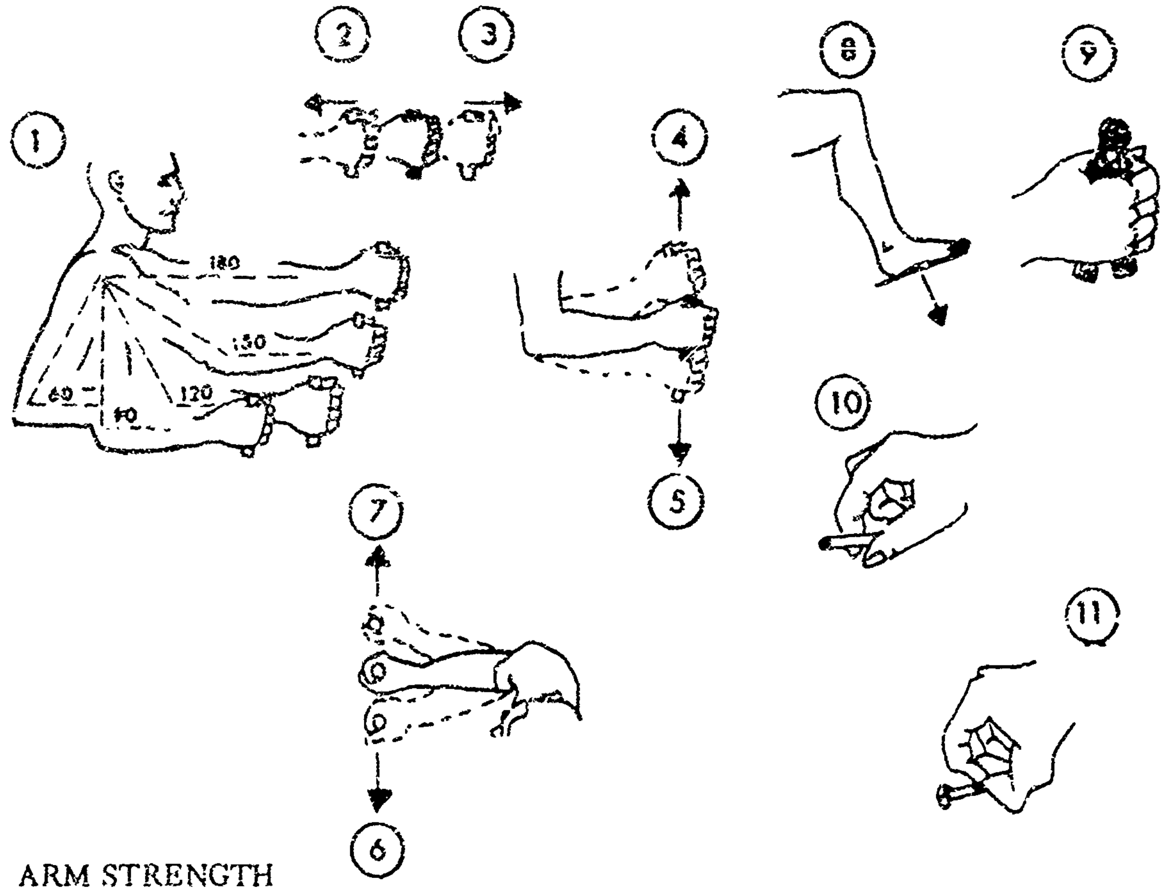


Fig. 21. Manual Lifting Capacity (using both hands)



ARM STRENGTH

(1) Degree of Elbow Flexion	(2) Pull R**	L	(3) Push R	L	(4) Up R	L	(5) Down R	L	(6) In R	L	(7) Out R	L
180°	52	50	50	42	14	9	17	13	20	13	14	8
150°	56	42	42	30	18	15	20	18	20	15	15	8
120°	42	34	36	26	24	17	26	21	22	20	15	10
90°	37	32	36	22	20	17	26	21	18	16	16	10
60°	24	26	34	22	20	15	20	18	20	17	17	12

LEG, HAND, AND THUMB FINGER STRENGTH*

	(8) Leg Push R	L	(9) Hand Grip R	L	(10) Thumb-Finger Grip (Palmar)	(11) Thumb-Finger Grip (Tips)
Momentary Hold	413	387	63	65	15	12
Sustained Hold	200	[illegible]	42	38	15	12

* Design values, in pounds, for the given actions
** R = Right L = Left

Fig. 22. Human Strength

Temporary Shelters

1. Temporary shelters should be provided, as necessary, to inclose and protect personnel and equipment during major maintenance and operational tasks. They should be designed so that:

a. The time to install is minimal.

b. Maximum practical enclosure and protection are provided in terms of the environment in which the shelter is to be used.

c. Ventilation and environmental control are within tolerable limits, considering the type of clothing to be worn.

d. Allowances are made for variations in configurations of the sheltered equipment.

e. They can be used side by side where appropriate.

f. They are compatible with, provide openings for, and allow employment of associated support equipments such as cranes, stands, slings, etc.

ENVIRONMENTAL WORKSPACE

General

1. When deviations from the stated tolerable conditions of this section become necessary, their consequences must be planned for in design to the degree that they may result in:

a. Requirements for protective clothing, devices, etc., which affect the mobility, reach, work space, access size, etc., for efficient and effective operation and maintenance.

b. Reduced human performance.

c. Borderline conditions which, though they have little or no direct effect on equipment, may seriously impair the ability of the operator or technician to perform effectively.

d. Conditions which, for the above or other reasons, contribute to longer maintenance time, or increased maintenance errors, oversights, erroneous decisions, etc., and which are detrimental to system availability and performance.

Atmospheric Environment

1. Suitable control of the atmospheric environment can frequently be achieved by the proper allocation and utilization of heating, cooling, and ventilating equipment or by the selection of insulating materials for personnel work areas. However, it may not always be feasible to provide direct control over the atmospheric environment, and some of the following methods may have to be used under adverse conditions:

a. Rotation of personnel at their work stations.

b. Decreased workloads.

c. Increased work space allotments.

d. Individual protective measures or supplemental equipment.

e. Personnel selection and training.

f. Acclimatization of operating personnel.

Surface Temperatures

1. Table 9 provides the effects on the skin of personnel coming in contact with surfaces at different temperatures.

TABLE 9

EFFECTS ON SKIN IN CONTACT WITH SURFACES AT DIFFERENT TEMPERATURES

Temperature (^{o}F)	Sensation or Effect
212	2nd-degree burn on 15-sec contact
180	2nd-degree burn on 30-sec contact
160	2nd-degree burn on 60-sec contact
140	pain; tissue damage (burns)
120	pain; "burning heat"
91 ± 4	warm; "neutral" (physiological zero)
54	cool
37	"cool heat"
32	pain
Below 32	pain; tissue damage (freezing)

2. The highly localized heat from power train components of mobile missile systems must be insulated to prevent the imposing of an excessive surface contact or ambient heat load upon the crew members.

Temperature Requirements

1. The optimum temperature range for personnel varies according to the nature of the tasks performed and the conditions under which the tasks are performed. For maximum physical comfort, the optimum range of effective temperature for accomplishing light work is 70-80° F. in a warm climate (or during summer) and 65-75° F. in a colder climate (or during winter). Effective temperature of the environment may be derived from Figure 23.

2. The effective temperatures ranges are flexible because they vary according to the amount of work activity. In general, the ranges should be extended upward for tasks requiring minimal physical effort and downward for tasks requiring continuous muscular exertion.

3. An effective temperature of 85°F should be considered the maximum limit for reliable human performance.

4. Minimum temperature requirements are dependent upon the tasks to be performed in specific applications. Heating should be provided within personnel enclosures utilized for detailed work or occupied during extended periods of time if the dry bulb temperature drops below 50° F.

5. Prolonged exposure to temperatures below 55° F. often results in a "stiffening" of fingers, thus degrading performance in tasks requiring manual dexterity.

6. In providing for heating and cooling of enclosed areas, it is important that the temperature of the enclosed area be held relatively uniform. The temperature of the air at floor level and at head level should not differ significantly, (10° F.).

Humidity Requirements

1. A relative humidity above 30% and below 70% is considered to be adequate if the optimum temperature range for physical comfort is maintained.

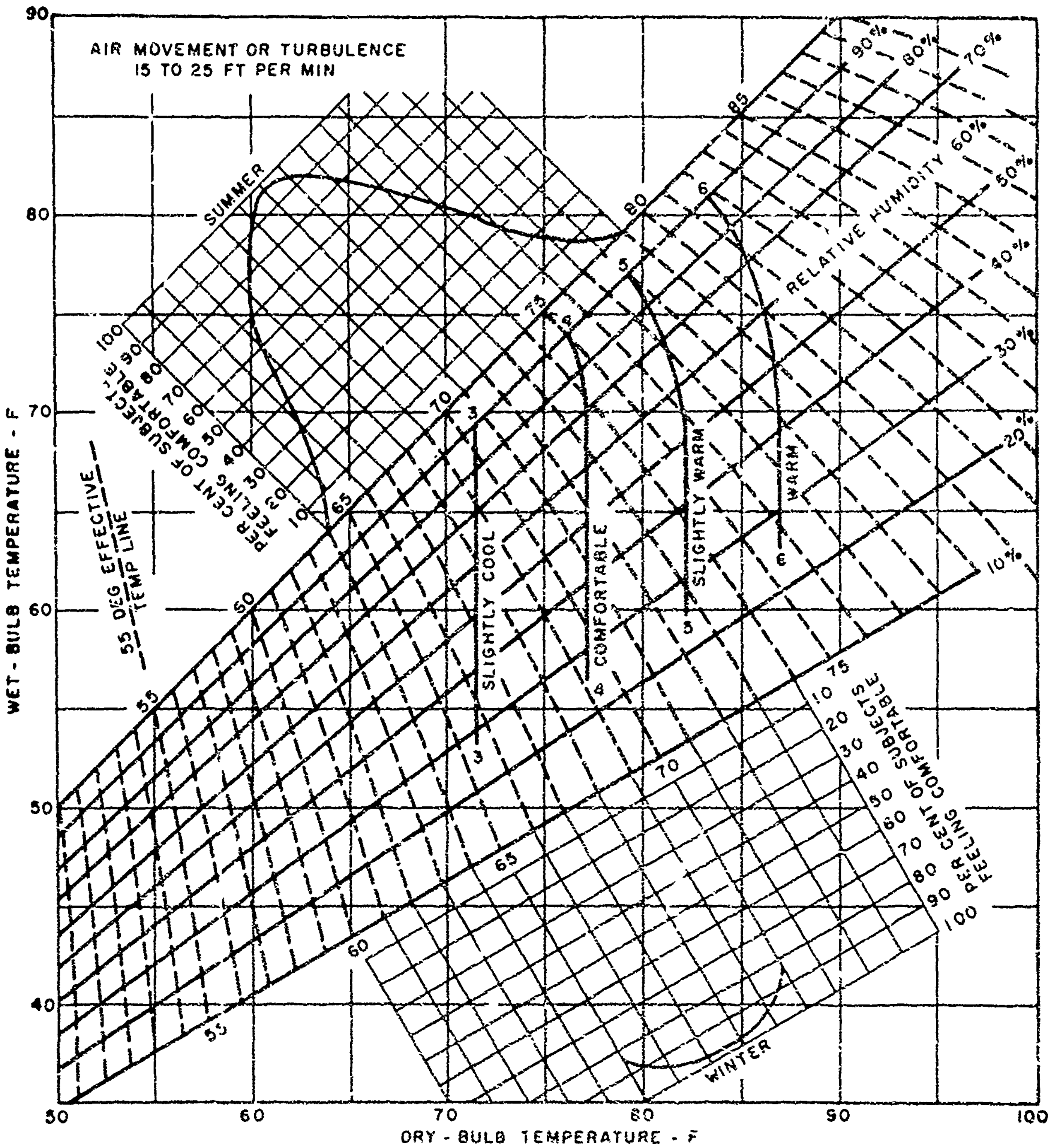


Fig. 23. Effective Temperature Chart
Clothing: Customary indoor clothing. Activity: Sedentary or light muscular work.
(Reprinted by permission from A.S.H.R.A.E. Guide and Data Book, 1963)

Ventilation and Circulation

1. Ventilation facilities should provide a minimum supply of 1000 cubic feet of fresh air per person per hour.

2. Air circulation around the operator should be less than 100 feet per minute and velocities less than 65 feet per minute are desirable.

3. Forced air systems hot or cold should be designed such that the hot or cold air discharge is not directed on personnel.

Atmospneric Contaminants

1. For maximum allowable concentration of gases, vapors, fumes, dusts, etc., the latest issue of Threshold Limit Values of the American Conference of Government Industrial Hygientists should be consulted.

2. Typical concentrations of dust associated with Army acitvities are contained in Table 10.

3. The effects on humans of carbon monoxide exposure for given times is shown in Figure 24.

4. Carbon monoxide concentrations should not exceed the following average values for the intervals indicated:

10 seconds	0.50 percent
20 seconds	.24 percent
40 seconds	.12 percent
1 minute	.08 percent
3 minutes	.03 percent
5 minutes	.02 percent
60 minutes	.01 percent
More than 60 minutes	.005 percent

5. The composition of the exhaust of multi-fuel engines and its effect upon personnel depends upon:

   a. The loading condition of the engine.

   b. The ambient temperature in which the engine is operating.

   c. The type of fuel.

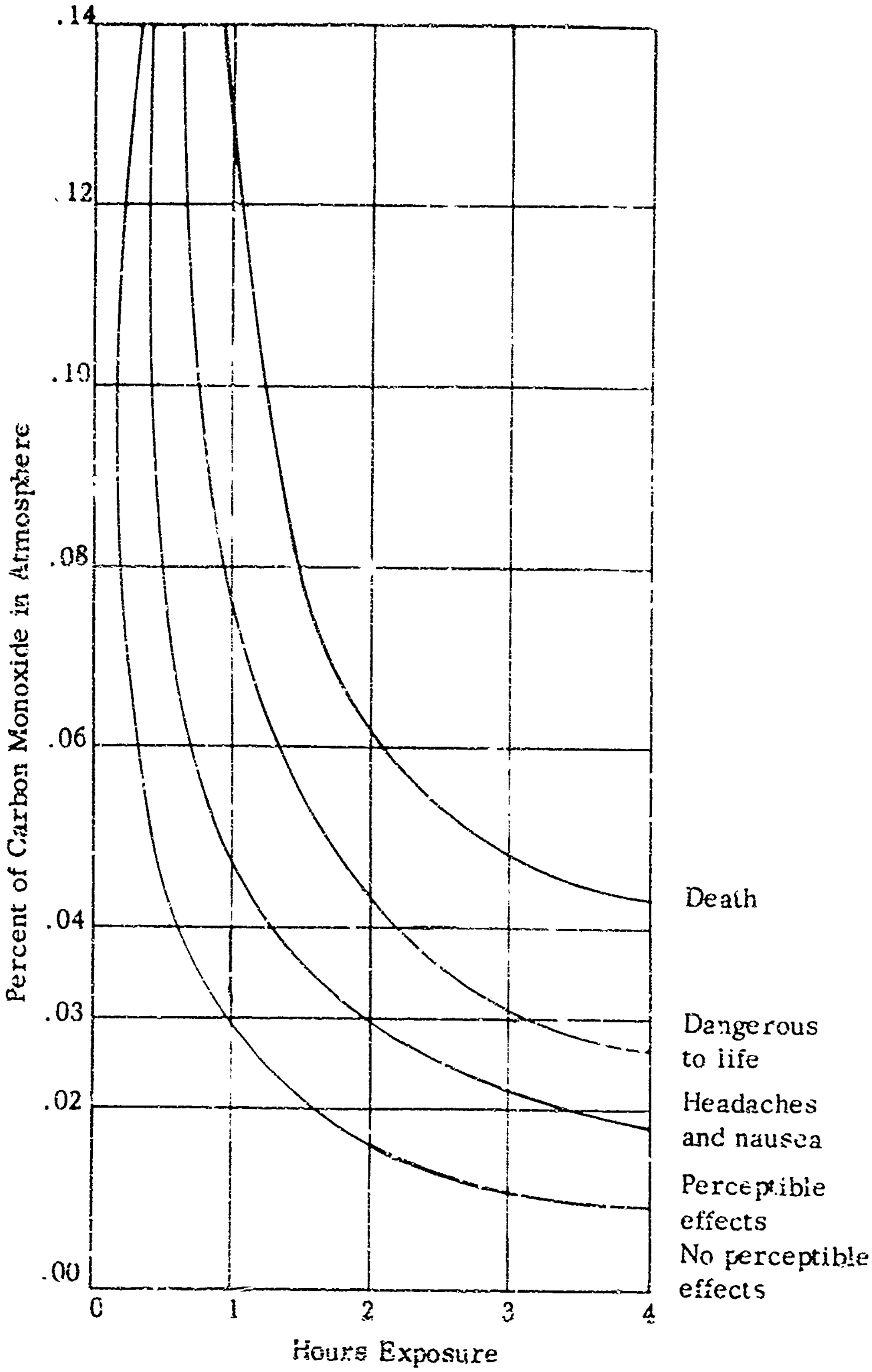


Fig. 24. Effects of Carbon Monoxide for a Given Time on Human Beings

6. When multi-fuel engines are using gasoline, the exhaust products are CO, CO_2, and H_2O.

7. When these engines are operated on CITE, JP4, or kerosene, the exhaust products are aldehydes, H_2O, CO_2, H_2 and free carbon.

8. When diesel fuel is used, the exhaust products are aldehydes, traces of nitrous oxides, sulphur compounds (SO_2, etc.), CO_2, H_2O, H_2 and free carbon.

9. The highest concentrations of the substances indicated in paragraphs 6, 7, and 8, will be found during starting and idling in cold weather for the fuels cited.

10. When multi-fuel engines are operated on CITE and diesel fuels, the exhaust products contain aldehydes which can cause eye irritation and nausea among personnel. Conjunctivitis and nausea have occurred among personnel exposed to these exhaust products, resulting in temporary disability. These temporary disabilities are common to conditions such as vehicles in convoy, the transportation of troops, and other situations where personnel are subjected to the exhaust stream of multi-fuel engines.

11. Careful consideration should be given in the design of compartments to provide sufficient ventilation to maintain these products below an irritating and nauseating level.

TABLE 10

Typical Dust Concentrations to Which Army Personnel are Exposed

Operations	Dust Concentrations Millions of particles per Cubic Foot
Minimum Activity	
Airborne dust from infantry camp; some from a road grader.	9.0
Motor pool of a medical battalion; slow traffic.	12.0
Bivouac area, Sunday afternoon, fresh breeze.	15.4
Div. Surg. tent, Hq., camp area.	21.0
Air base; planes taking off clean runway.	21.7
Motor Pool; ambulance driving in loose sand.	22.5
Infantry training on regt. parade ground.	25.0
Ordnance unloading depot. Only three vehicles moving.	27.7
Army truck road. Dust raised by staff car.	27.7
Regimental area of camp; normal traffic.	29.0
Gas dump; no vehicular movement. Light to no breeze.	29.2
Repeated passage of 1/4-ton truck on tank trail.	29.2
Railhead with light traffic; no convoy movements.	31.0
Railhead with little traffic.	32.0
Hq., camp; light traffic, fresh breeze.	32.2
Ordnance unloading depot; heavy wind storm, no traffic.	34.5
Moderate Activity	
Infantry column; four companies ahead of sampler.	41.0
In convoy behind half-track.	41.2
Ass't driver's seat; light tank midway of column of tanks (Co.)	42.7
Evacuation hospital area; sandy surface, fresh breeze.	44.2
Corner tank battalion motor pool; 16 tanks and 1 truck moved.	48.7
Entrance to railhead; almost continuous truck traffic.	51.0
Troops drilling --no traffic.	51.7

TABLE 10 Continued

Operations	Dust Concentrations Millions of Particles per Cubic Foot
High Activity	
Maneuver road; dust raised by staff car.	75.00
Convoy of cargo trucks spaced 100 yards.	79.00
From 1/4-ton truck and wind-blown dust.	104.0
Deliberate dust disturbance by 1/4-ton truck.	113.0
Convoy of trucks and towed 75mm guns.	131.0
Repeated passage of 1/4-ton truck through pulverized silt bed.	160.0
Alongside moving tank column.	187.0
Inside tank following another 150 yards.	219.0
Convoy of trucks passing by.	250.0
Following 1/4-ton truck.	472.0
Thirty feet behind half-track; loose sand.	750.0
Extreme Activity (conditions deliberately fixed for maximum dustiness)	
Medium tank operating alone on dry driving range, 10 mph.	145.0 - 350.0
One tank trailing another, dry driving range, 10 mph.	610.0 - 700.0
Midway of column of 6 light tanks, driving into wind.	1250.0 - 1500.0
End of column of 5 light tanks, 10-15 mph.	250.0
Five tanks in wedge, sampled in 6th center tank.	450.0

Summary	Average	Range
Minimum activity	25.0	9.0 to 35.0
Moderate activity	46.0	41.0 to 52.0
High activity	231.0	75.0 to 750.0
Extreme activity	620.0	145.0 to 1500.0

Illumination

1. Requirements for appropriate illumination cannot be satisfied merely by providing a sufficient amount of light to perform tasks. Proper attention should also be given to the following factors:

a. The brightness contrast between each visual task object and its background.

b. Glare from work surfaces and light sources.

c. The level of illumination required for the most difficult tasks.

d. The color composition of the illumination source and the equipment surfaces.

e. Time and accuracy required in task performance.

f. Possible variations in operating conditions, i.e., outdoor panel black-out operation outdoor panel visibility under bright sunlight, etc., which may affect the lighting system, the task requirements, or personnel.

2. In the event of normal lighting system failure, the design should provide for emergency lighting (approximately 5 foot candles) to enable personnel to operate important controls or to find exit from the system.

Illumination Levels and Distribution

1. The examples of illumination levels expressed in Table 11 are presented so the designer may estimate the illumination requirements for those tasks within the system that are not directly related to the tasks of Table 12.

TABLE 11

REPRESENTATIVE EXAMPLES OF ILLUMINATION REQUIREMENTS

	Illumination Levels (in foot candles) Recommended	Minimum	Lighting source
Perception of small detail under low contrast conditions - for prolonged period of time, or - where speed and accuracy are essential (Examples: small component repair; inspection of dark materials)	125	100	Special Fixture
Perception of small detail under conditions of fair contrast - where speed or accuracy are not so essential (Examples: drafting: electronic assembly)	100	50	Special Fixture
Prolonged reading, desk or bench work, general office and laboratory work (Examples: assembly work; record filing)	50	25	Local
Occasional reading, recreation, sign reading - where visual tasks are not prolonged (Example: bulletin board reading)	20	10	General
Perception of large objects with good contrast (Example: locating objects in bulk supply warehouse)	10	5	General
Passing through walkways, handling large objects (Example: loading from a platform)	5	2	General

TABLE 12

SPECIFIC TASK ILLUMINATION REQUIREMENTS

Illumination Levels

Work Area or Type of Task	Foot Candles* Recommended	Foot Candles* Minimum
Assembly, missile component	30	25
Assembly, general		
course	20	10
medium	50	30
fine	100	75
precise	300	200
Bench work:		
rough	20	10
medium	60	50
fine	100	75
extra fine	300	200
Business machine operation (calculator, digital, input. etc.)	50	40
Console surface	50	25
Corridors	5	5
Circuit diagram	100	50
Dials	30	25
Electrical equipment testing	50	30
Emergency lighting	--	3
Gages	30	25
Hallways	5	5

*As measured at the task object or 30 inches above the floor.

TABLE 12 Continued

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Inspection tasks, general:		
rough	20	10
medium	60	50
fine	100	75
extra fine	300	200
Machine operation, automatic	30	25
Meters	30	25
Missiles:		
repair and servicing	50	50
storage areas	10	5
general inspection	50	30
Office Work, general	30	25
Ordinary seeing tasks	30	25
Panels:		
front	50	30
rear	10	--
Passageways	5	5
Reading:		
large print	10	5
newsprint	25	10
handwritten reports, in pencil	20	10
small type	30	25
prolonged reading	50	40
Recording	50	40

TABLE 12 Continued

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Repair work:		
general	50	30
instrument	100	100
Scales	30	25
Screw fastening	30	20
Service areas, general	10	5
Stairways	10	10
Storage:		
inactive or dead	5	2
general warehouse	5	5
live, rough or bulk	5	5
live, medium	10	10
live, fine	20	15
Switchboards	30	25
Tanks, containers	20	10
Testing:		
rough	20	15
fine	30	25
extra fine	100	75
Transcribing and tabulation	50	40

Note: Some unusual inspection tasks may require up to 1000 foot candles of light.
Note: As a guide in determining illumination requirements the use of a steel scale with 1/64 inch divisions requires 180 foot candles of light for optimum visibility.

Illumination Contrast

1. The contrast ratios between lightest and darkest areas should be as follows:

Ratio	Condition
3:1 Max	Between points on a console surface.
5:1 Min*	Between task and adjacent surroundings.
10:1 Max	Between task and remote surfaces.
40:1 Max	Between the immediate work area and the remainder of the environment.

2. If more than one brightness of paint is used, designers should avoid sharp differences in brightness. If contrast is needed, consider the use of different colors rather than allowing widely different brightness.

Glare

1. One of the most serious of all illumination problems is glare or dazzle. Glare not only reduces visibility for objects in the field of view, but causes visual discomfort.

2. Direct glare refers to a light source within the visual work field and should be controlled by:

   a. Avoiding bright light sources within 60^{o} of the central visual field. Since most visual work is on or below a horizontal level from the eye, direct luminaries placed high above the work area minimize direct glare.

   b. Using indirect lighting.

   c. Using a greater number of less intense light sources rather than a few intense ones.

   d. Using polarized light shields, hoods or visors to block the source in confined areas.

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* Transilluminated console components, i.e., legend lights, should be readily detectable in the presence of the greatest ambient illumination available.

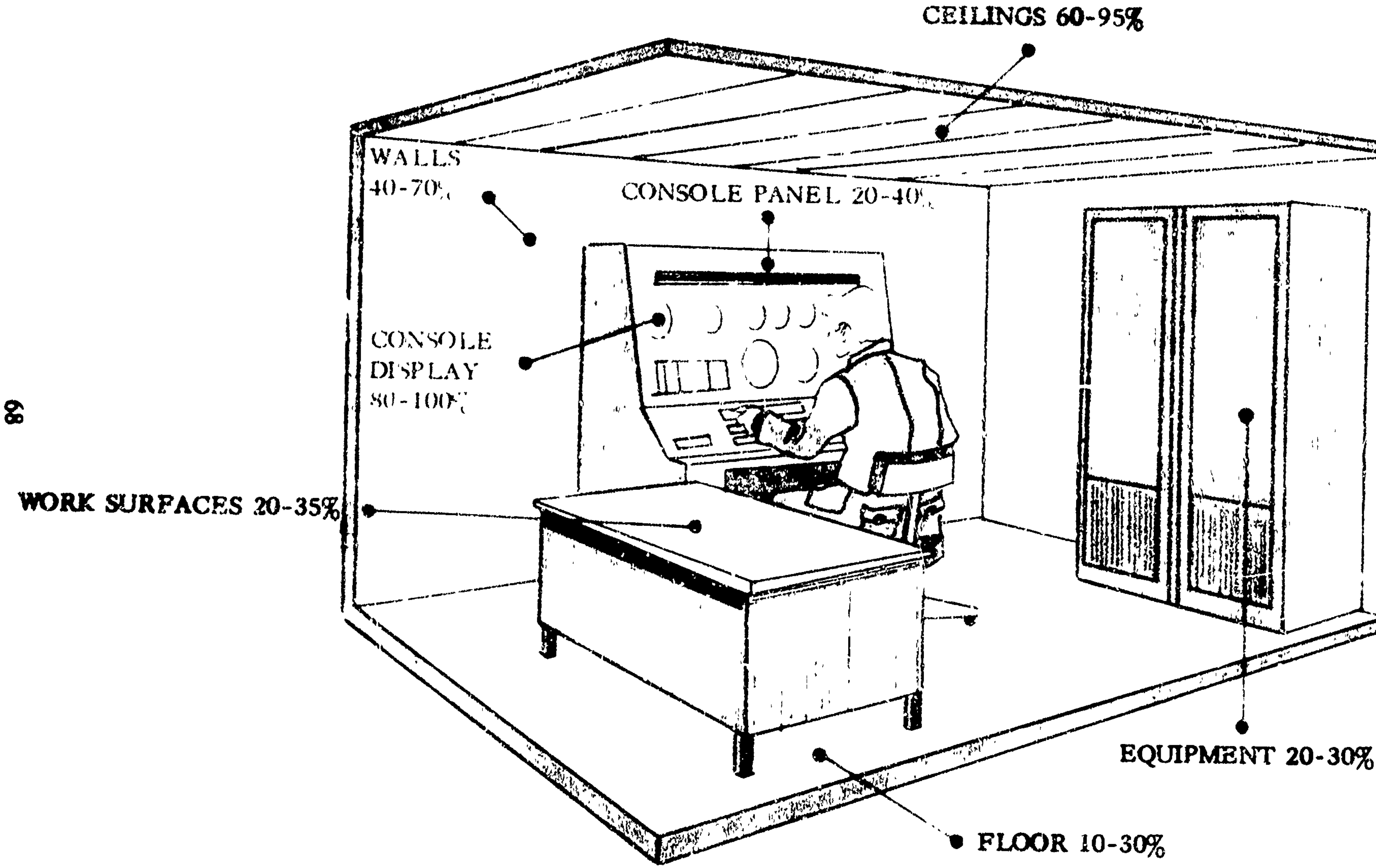


Fig. 25. Work Space Reflectance Values

3. Reflected glare refers to reflecting bright surfaces within the visual field and should be controlled by:

a. The use of surfaces that diffuse rather than specularly reflect incident light.

b. The arrangement of direct light sources so that the viewing angle of the visual work area is not equal to the angle of incidence from the source.

4. The glare control methods outlined above assume that the operator has unaided vision. When eyeglasses are worn they will reflect glare into the eyes if a bright light source to the rear of the viewer is less than 30° above or 45° below the line of sight. Glare will also be reflected if the light source to the rear is within a 20° horizontal deviation from the line of sight.

5. Reflected glare from work surfaces is a common, but frequently overlooked, cause of inefficiency in visual tasks.

Reflectances

1. Generally recommended surface reflectance values for workplaces such as power stations, control rooms, offices and maintenance areas are indicated in Figure 25.

2. The large surface areas of the space should be non-glossy. Some non-critical small areas such as door frames and molding may be glossy if ease of cleaning is essential.

3. Non-saturated colors such as tints, pastels, and warm grays should be used on all large surface areas.

Color

1. Where current regulations do not specify colors or where the procuring activity does not specify colors, the following colors selected from FED-STD-595 should be used as applicable:

2. Interior Areas and Equipments

Ceiling	27875 White
Console Exterior	24410 Green
Console Interior	37875 White (used only where maintenance and troubleshooting are required within the console. Otherwise, standard requirements for an economical internal protective finish apply.)
Floors	36118 Gray
Handles	37038 Black
Lettering	37038 Black
Panels	26492 Gray
Walls	24410 Green

3. Exterior Equipment

Covers	24087 Olive Drab
Handles	37038 Black
Lettering	37038 or use 37875 White on Olive Drab surfaces
Panels	26492 Gray

Dark Adaptation

1. Adaptation is the process by which the eyes become accustomed to changes in the level of illumination. The time it takes to accustom the eyes to a darkened room is about 15 minutes - to dark adapt the eyes requires 30 minutes or more. The time required to dark adapt depends on the color and intensity of the previous light.

2. When the illumination is above approximately 0.01 lumen per square foot, color can be perceived; when it is below approximately 0.001 lumen per square foot, color cannot be perceived.

3. Low brightness red light is most satisfactory in situations where maximum dark adaptation is a system requirement. The red light is normally obtained by use of a filter that will only pass wavelengths longer than 620 millimicrons (red). A higher cut-off filter would be slightly superior for dark adaptation since the eye would receive even less excitation; however, an excessive proportion of the available light energy would be wasted.

4. Where dark adaptation is a system requirement, instrument or display markings should be illuminated with red light (620 millimicrons and above). The brightness of the markings should not be less than 0.02 foot lamberts nor more than 0.1 foot lamberts.

Noise

Speech Interference Level

1. Communications may be affected by ambient noise, i.e., surrounding noise, and by noise in the communication system itself.

2. The speech interference level (SIL) describes the effectiveness of noise in masking speech. It is defined as the average, in dB, of the sound levels of the masking noise in the three octave bands of 600 to 1200; 1200 to 2400; and 2400 to 4800 cps. The accuracy of prediction may be increased in certain noise spectra by the addition of the 300-600 cps band to the average when the sound pressure level in the 300-600 cps band exceeds the sound pressure level in the 600-1200 cps band by 10 or more decibels. The SIL cannot be used if the masking noise containes intense low-frequency components or if the noise is concentrated in a narrow band. The effect of noise on voice communication is shown in Figure 26.

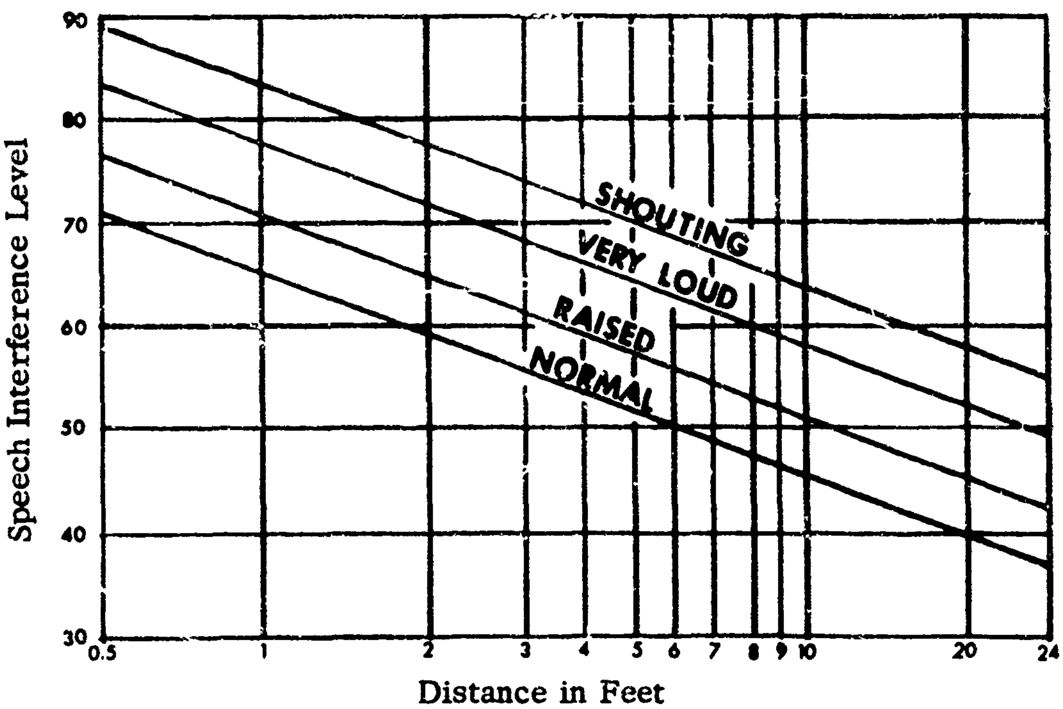


Fig. 26. Person to Person Communications

Equipment Design Criteria

1. When steady state noise sources are present in the environment, i.e., on vehicle generators, air conditioners, etc., the maximum noise level for Army Materiel Command equipment should not exceed HEL Standard S-1-63B. Table 13 contains the maximum noise level for equipment as extracted from HEL Standard S-1-63B. For noise level measurements and use of ASA Preferred Frequency see HEL Standard S-1-63B.

2. When pure tones, or narrow bands of noise, are present in any octave band, the sound pressure level of that octave band will be reduced by 5 dB for frequencies above 1000 cps and 10 dB for frequencies below 1000 cps from that level shown in Table 13.

TABLE 13

Maximum Steady State Noise Level for Army Materiel Command Equipment

(Commercial Frequencies ASA Z24.10-1953)

Octave Band Limits (cps)	Center Frequency (cps)	Noise Level (dB)
37.5 - 75	53	120
75 - 150	106	115
150 - 300	212	109
300 - 600	425	101
600 - 1200	850	93
1200 - 2400	1700	89
2400 - 4800	3400	89
4800 - 9600	6800	91

3. Where continuous person to person (non-electrically aided) communication of information is a system requirement, the steady state noise level should not exceed that shown in Table 14. For noise level measurement and use of ASA Preferred Frequency see HEL Standard S-1-63B.

TABLE 14

Maximum Steady State Noise Level for Non-Electrically Aided Person to Person Communication

(Commercial Frequencies ASA Z24.10-1953)

Octave Band Limits (cps)	Center Frequency (cps)	Noise Level (dB)
37.5 - 75	53	79
75 - 150	106	73
150 - 300	212	68
300 - 600	425	64
600 - 1200	850	62
1200 - 2400	1700	60
2400 - 4800	3400	58
4800 - 9600	6800	57

Vibration Effects on Performance

1. Performance is adversely effected to the degree that vibration:

   a. Can, at high levels, cause critical body damage.

   b. Makes dials, lettering, and sight reticles difficult to read.

   c. Makes controls, tools or other objects difficult to manipulate.

   d. Contributes to increased fatigue, nervousness, and irritability that can lead to oversights, errors in judgment, etc.

   e. Increases difficulty of retaining head in sight eyecups, thereby allowing undesirable stray light to enter the eye.

Vibration Limits

1. In the design of equipment, vibration should be:

   a. Minimized wherever practical in design.

   b. Kept below the "strongly noticeable" and "recommended limit" range of Figure 27 wherever practicable.

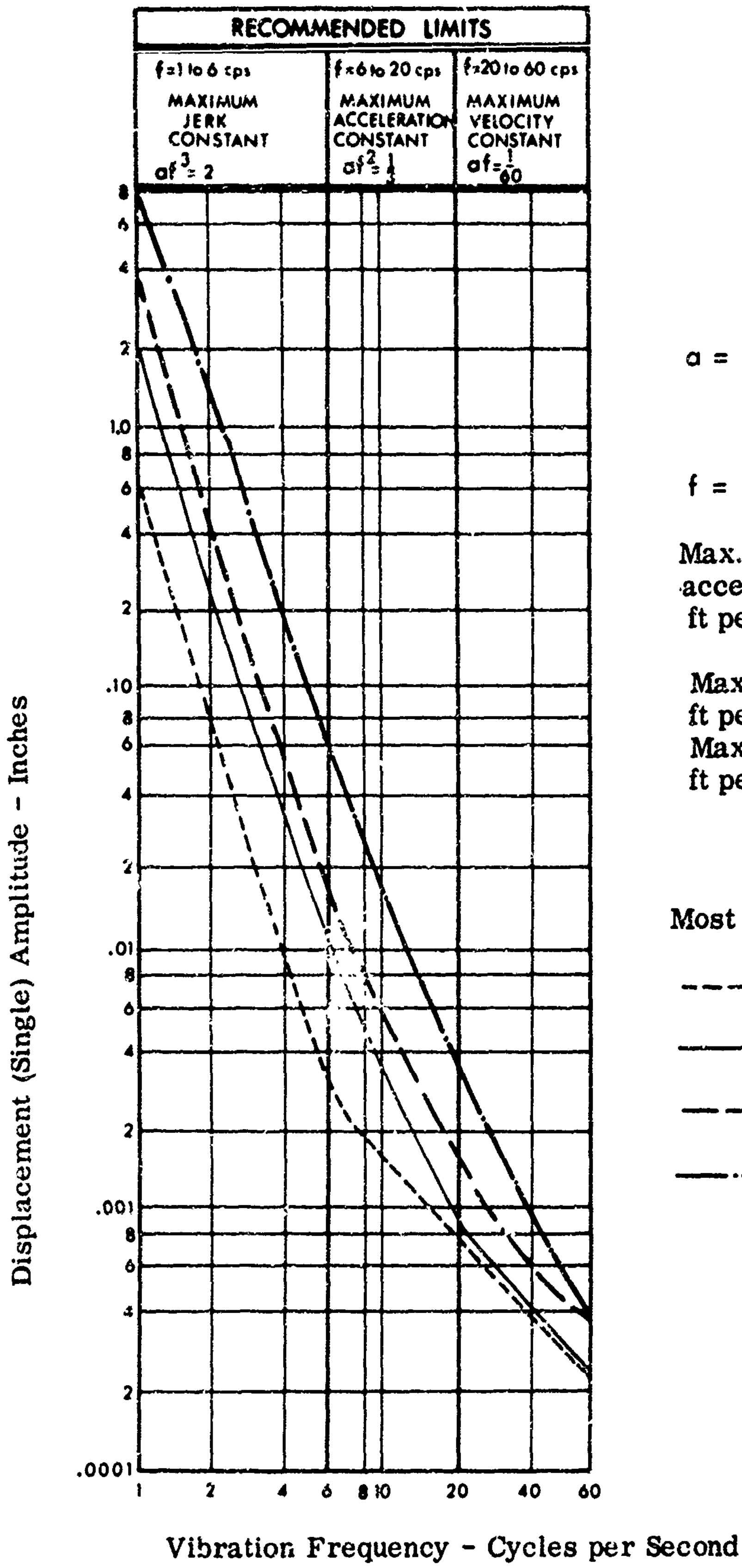
   c. Never allowed to approach the "uncomfortable" to "extremely uncomfortable" range of Figure 27.

2. Vibration can be reduced and controlled by:

   a. Isolating equipment from vibration cources by shock mountings, fluid couplings, etc.

   b. Providing proper balance of rotating elements of equipment.

   c. Providing damping materials or cushioned seats (see Section 3.0) for standing or seated personnel.



DEFINITIONS

a = Amplitude of vibration, inches (max. displacement from static position.)

f = Frequency of vibration, cycles/sec.

Max. rate of change of acceleration (Jerk) $= \frac{2}{3}\pi^3 af^3$, ft per sec^3

Max. acceleration $= \frac{1}{3}\pi^2 af^2$, ft per sec^2

Max. velocity $= \frac{1}{6}\pi af$, ft per sec.

LEGEND

Most Sensitive Reactions

- - - - - - - Strongly Noticeable

———— Recommended Limit

— — — — Uncomfortable

—·—·— Extremely Uncomfortable

Fig. 27. Human Reaction to Vertical Vibrations

Radiation

1. Radiation is a problem that becomes increasingly important as new uses and handling methods come into being. The health hazards of radiation are fairly well known and extremely dangerous.

2. Protective devices, and determination of permissible dosages and rate, change as new data are determined; therefore, the U. S. Army Surgeon General should be contacted for the latest available data.

Electromagnetic

1. The maximum allowable exposure of personnel to microwave energy is given in . 40-583.

Nuclear

1. For the maximum allowable exposure of personnel to nuclear radiation, direction should be obtained from the Atomic Energy Commission and the U. S. Army Surgeon General.

CONSOLES

Design and Layout

1. The effectiveness with which the operator performs his tasks will depend upon:

   a. Designing the contours and slopes of the console or instrument panel to minimize parallax in viewing displays.

   b. Locating controls so they can be easily manipulated

   c Providing adequate space and supports for the operator.

2. There is no configuration for consoles or instrument panels that is acceptable for all applications. There are, however, certain configurations which are more effective than others. These are:

   a. Fig. 31 illustrating surfaces and slopes for seated operations.

   b. Fig. 32 illustrating console for seated operations where the operator must be able to look over the top of the console.

   c. Fig. 33 illustrating a console for sit-stand operations.

   d. Fig. 34 illustrating a console for standing operation.

   e. Fig. 35 illustrating "wrapped around" configuration where the panels are grouped radially about the operator. This latter arrangement permits more controls and displays to be placed within the operator's manual and visual workspace. However, this configuration is limited to use by a single operator.

3. The various surfaces on consoles or instrument panels can be classified in terms of primary and secondary display and control areas. Each of these areas are discussed and guidelines for their use provided.

Display Surfaces

1. The primary display surfaces for the console configurations are illustrated in Figures 31 through 34. In general, this area corresponds to the preferred viewing of Fig. 28.

2. The primary visual surface on consoles or instrument panels should be reserved for displays which are used frequently or are critical to successful operation. Special cases where controls and displays are combined or control and display compatibility is important, even though the displays are of secondary importance, may warrant their placement on this surface.

3. The secondary display surfaces are located above or to the side of the primary display surfaces, see Figure 31.

4. The secondary visual surface should be used for displays which are used infrequently during operations, e.g., set-up, adjustment, or operationally non-critical functions.

5. The designer should use the following principles in the layout of displays upon the console or instrument panel:

a. Frequently monitored displays should be within the operator's preferred viewing area, see Figure 28.

b. Indicators that are used for long, uninterrupted periods should be in the preferred position.

c. The preferred distance to displays is 28".

d. The viewing distance to displays should not be less than 10-12" for short viewing periods; preferably not less than 16".

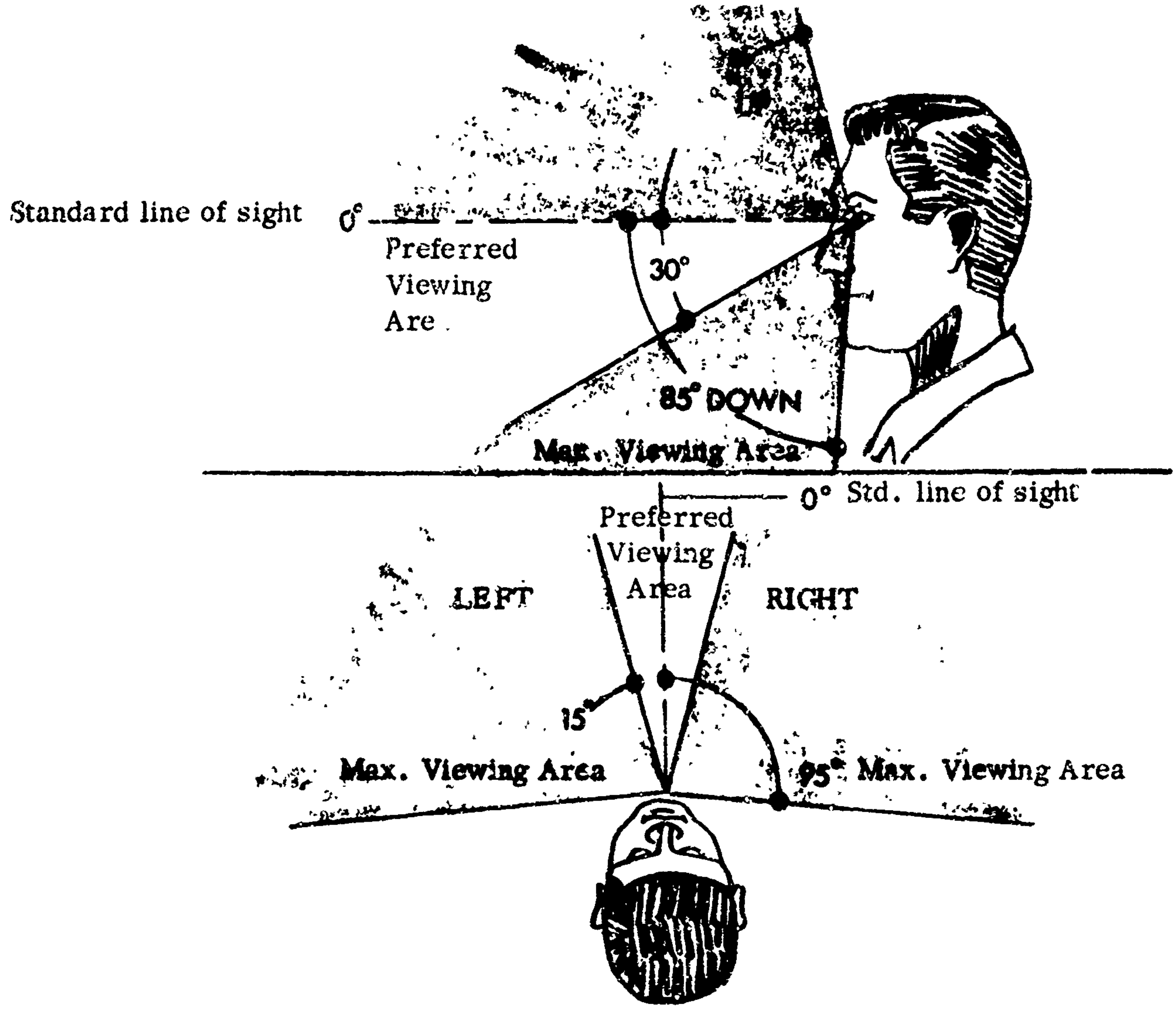
e. Displays requiring accurate readout should be located closer to the operator's line of sight than displays requiring gross monitoring.

f. Displays should be mounted perpendicular to the line of sight. Angular deviation from the line of sight (see Fig. 28) of up to 45° may be acceptable provided that accurate instrument reading is not essential and parallax is not too great.

g. All instruments and legends should be readable from the normal head position of the operator allowing for normal head rotation and restrictions imposed by helmets or other head gear.

h. All displays necessary to support an operator activity or sequence of activities should be grouped together.

i. Infrequently used displays can be in the periphery (maximum viewing area) of the visual field, see Figure 28.



	Preferred*	Maximum*	
		Eye Rotation Only	Head and Eye Rotation
UP	0°	25°	75°
Down	30°	35°	85°
Right	15°	35°	95°
Left	15°	35°	95°

* Display area on the console defined by the angles measured from the standard line of sight.

Fig. 28. Viewing Area

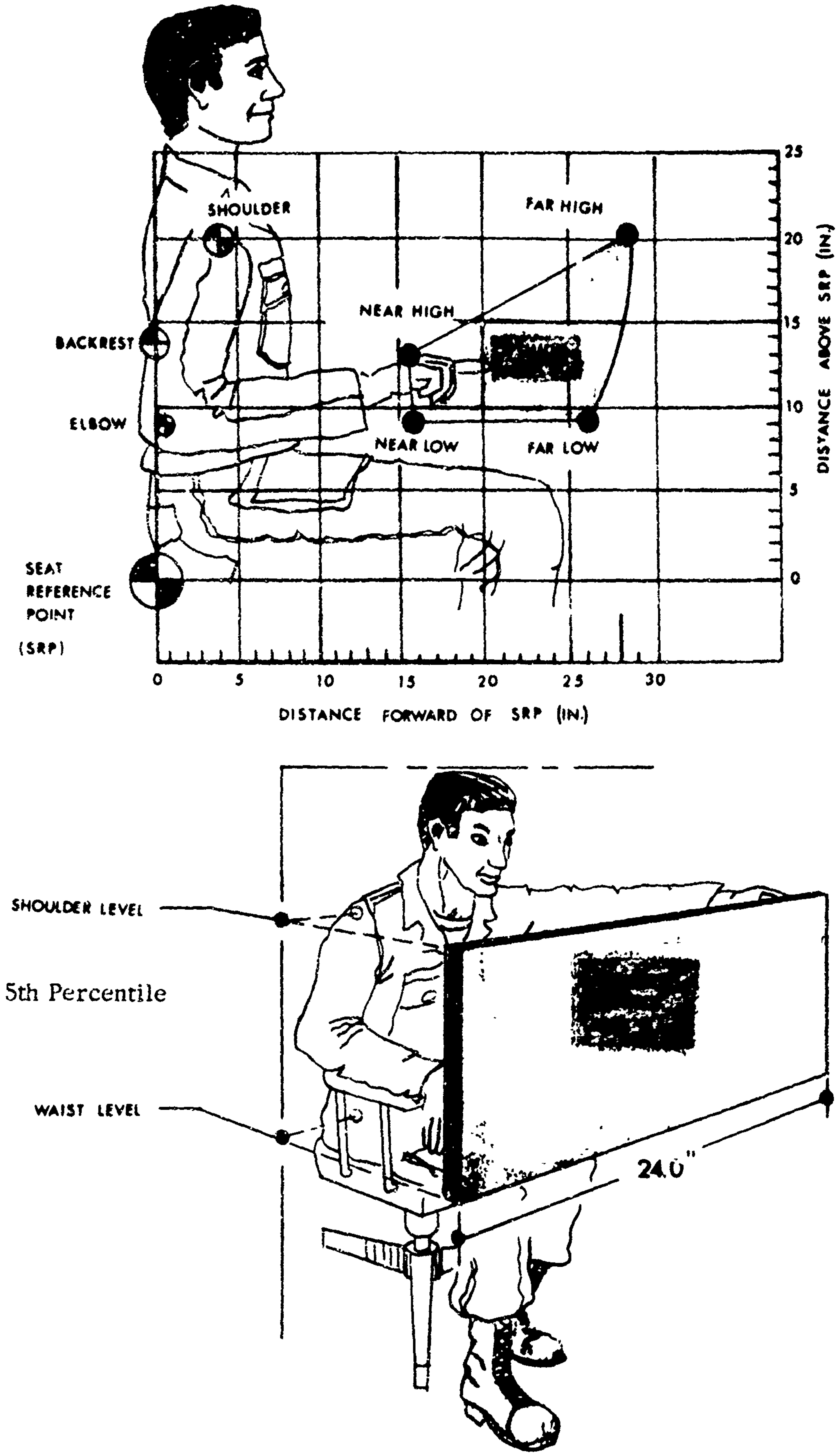


Fig. 29. Seated Optimum Manual Control Space

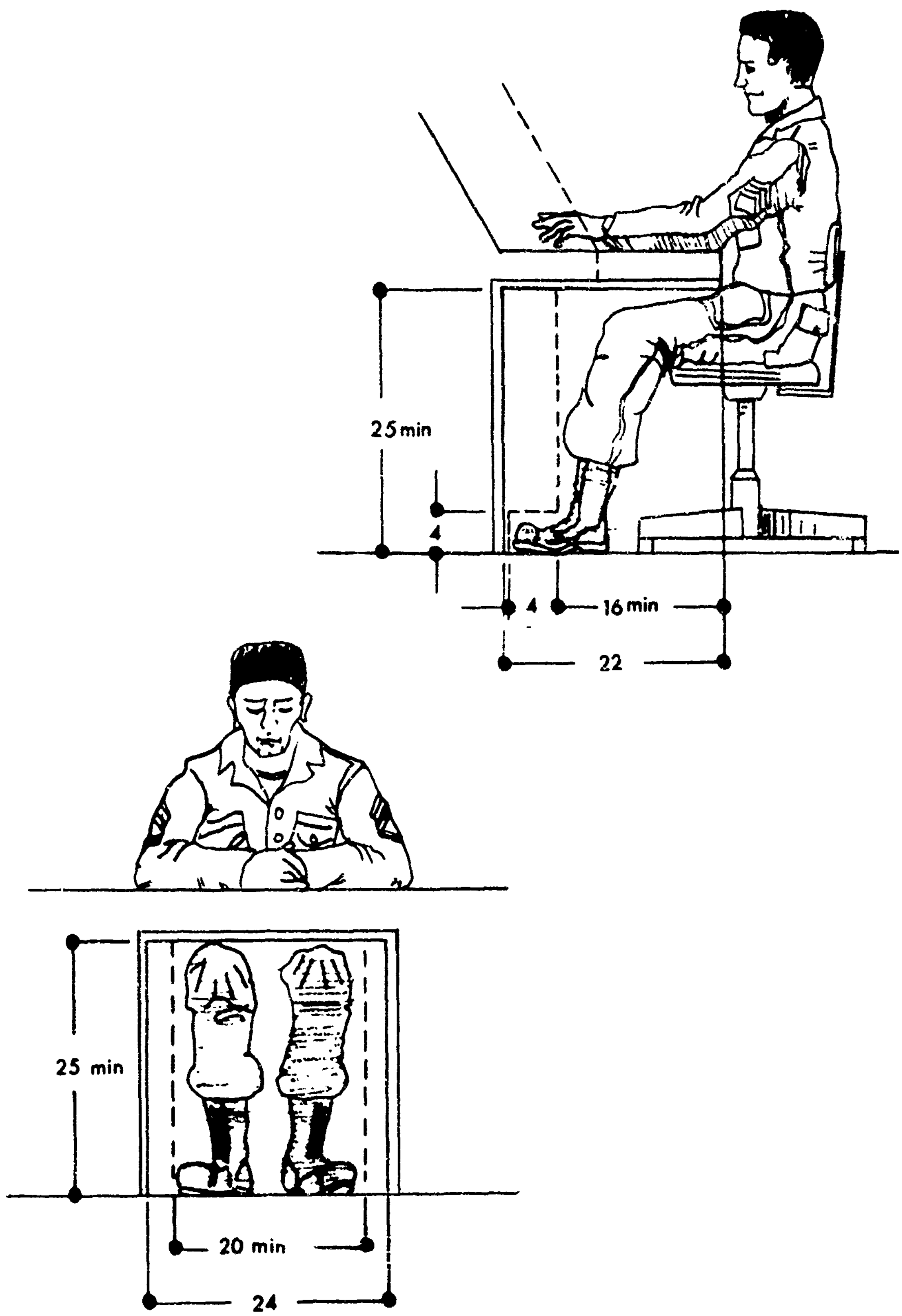


Fig. 30. Console Leg Room Dimensions (Seated Operator)

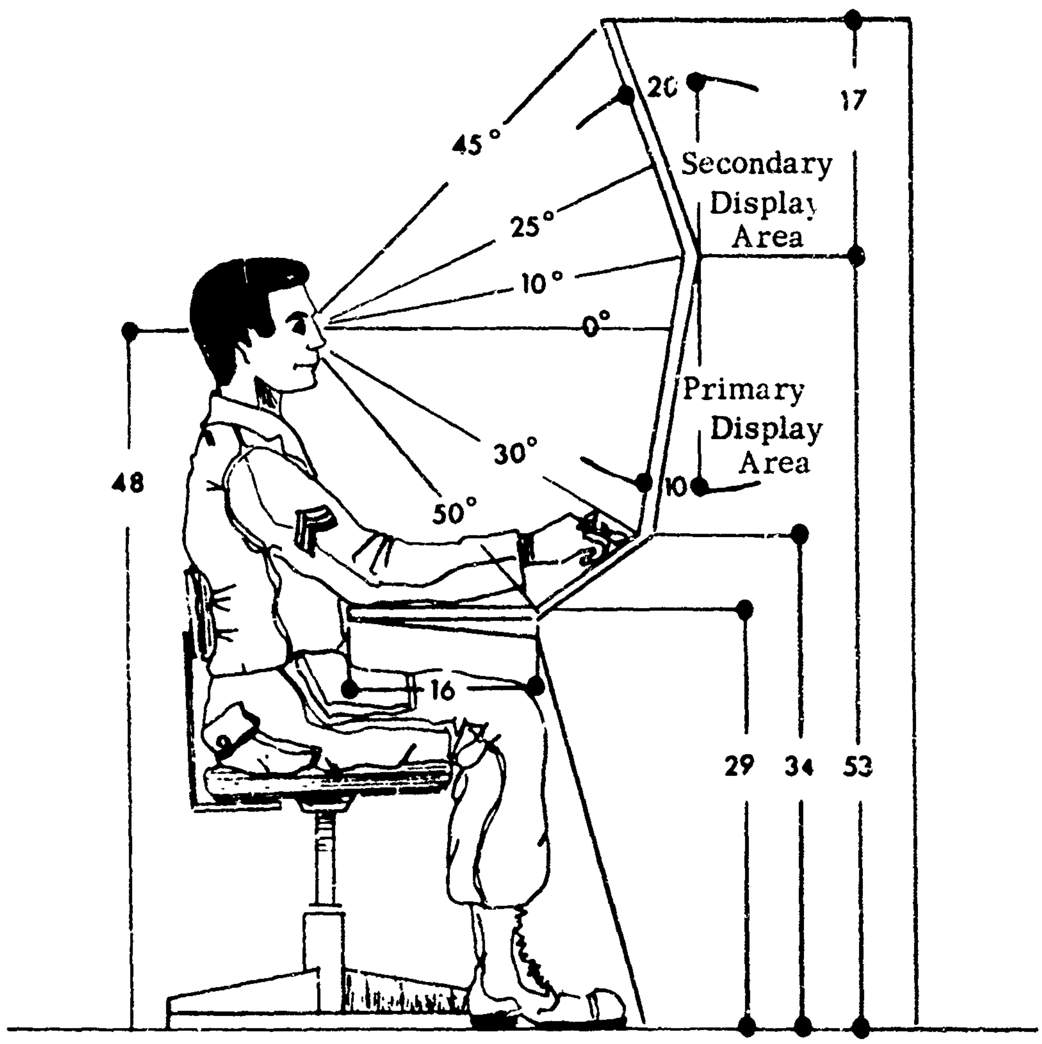
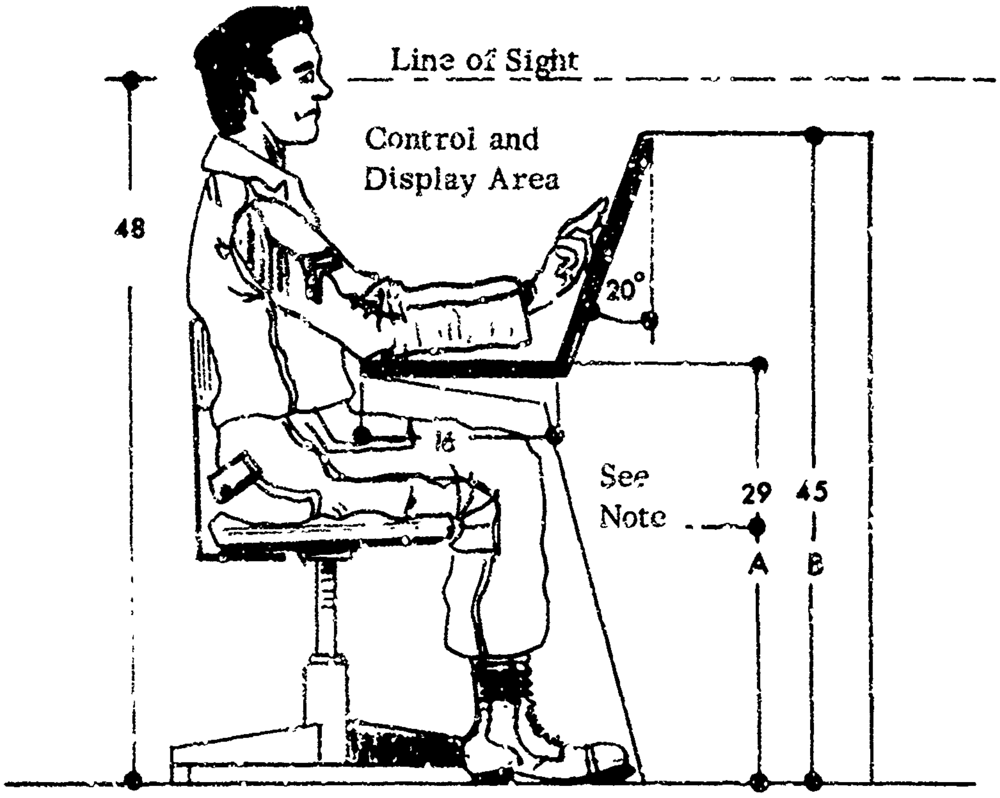


Fig. 31. Console Dimensions for Seated Operators (Compound Panel)



NOTE: Increase dimension "A" to 42" and "B" to 58" for standing operation with lookover requirement to maintain the same relationships.

Fig. 32. Console Dimensions for Seated Operators (Simple Panel)

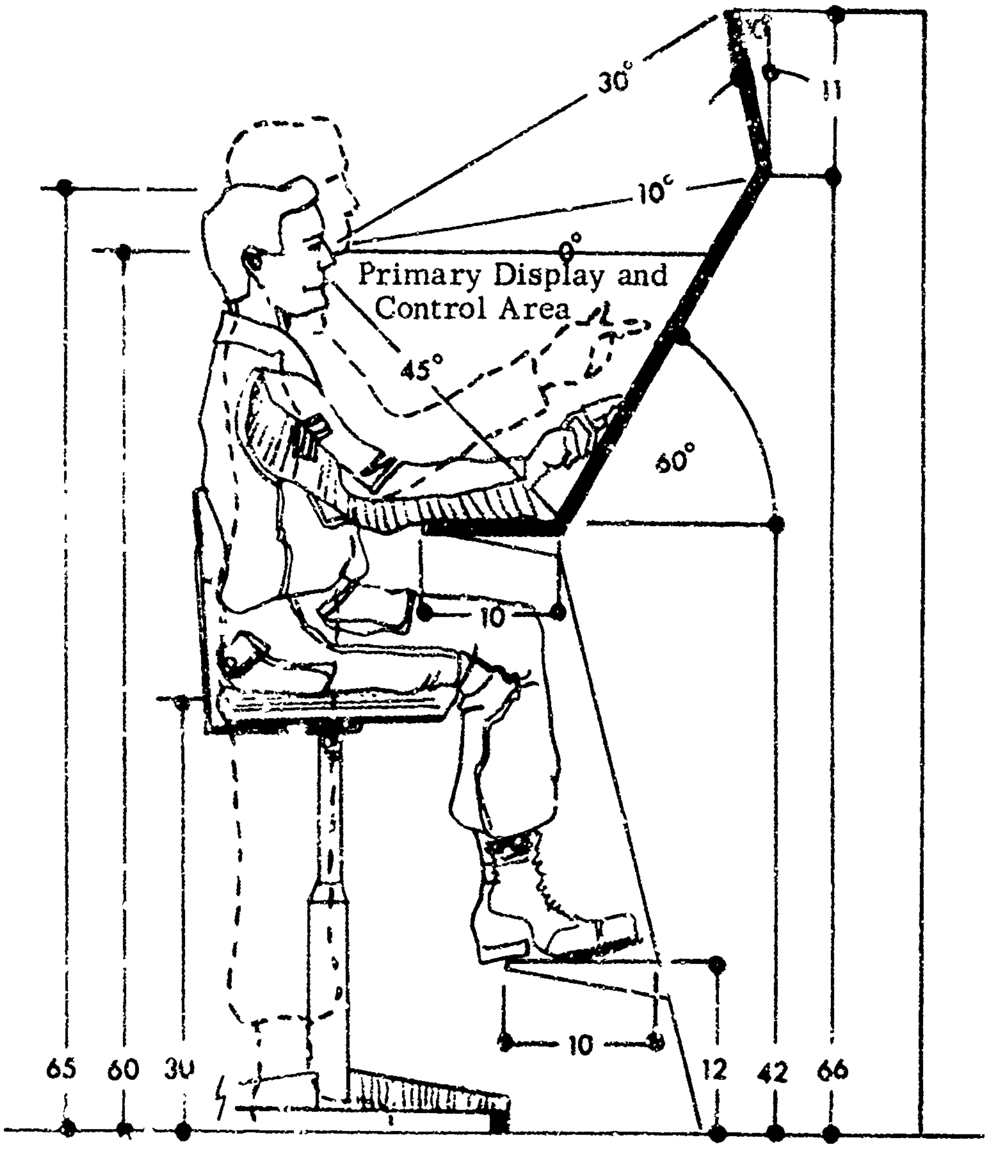


Fig. 33. Console Dimensions for Sit-Stand Operators

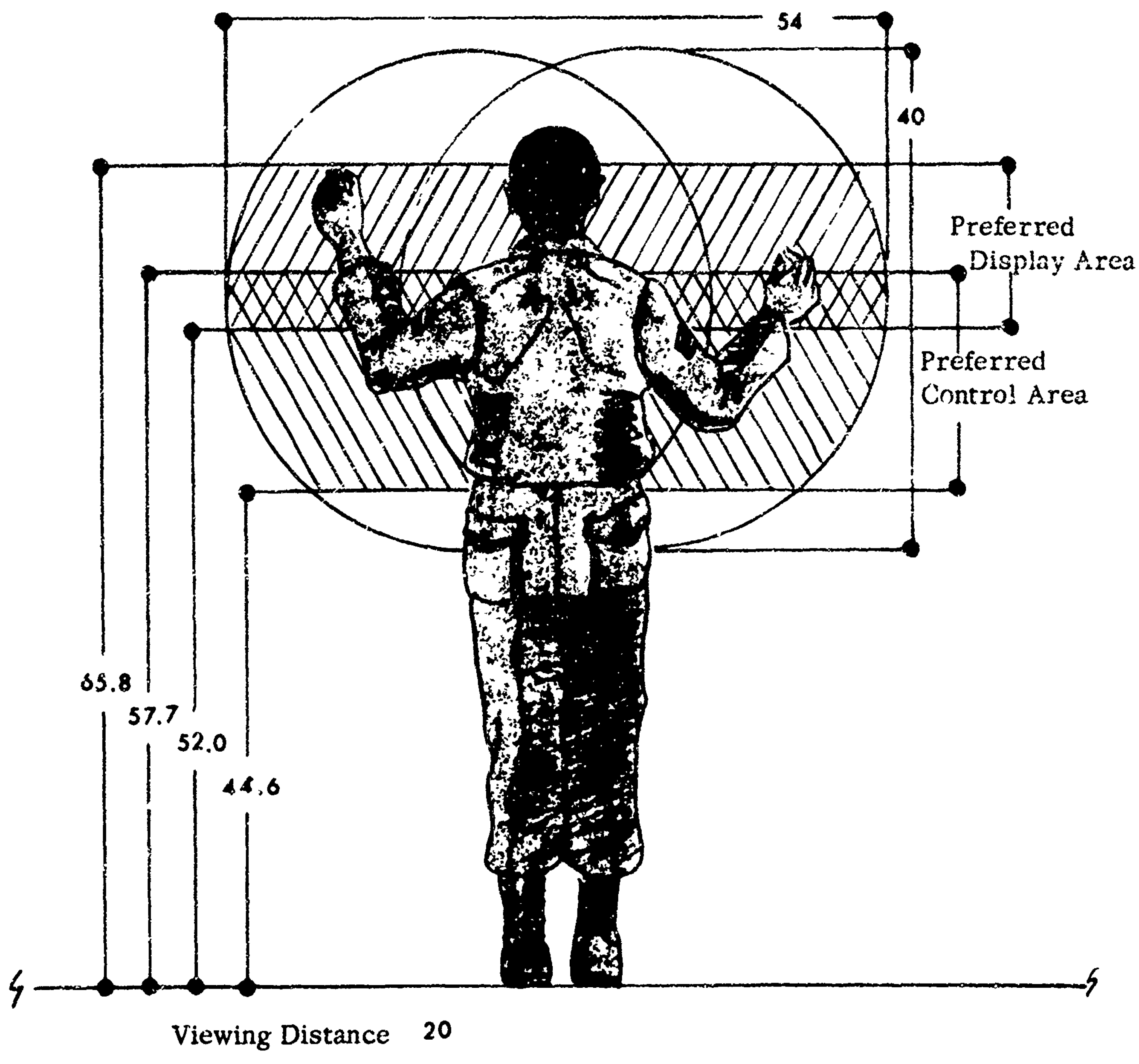


Fig. 34. Console Dimensions for Standing Operators (Flat Panel)

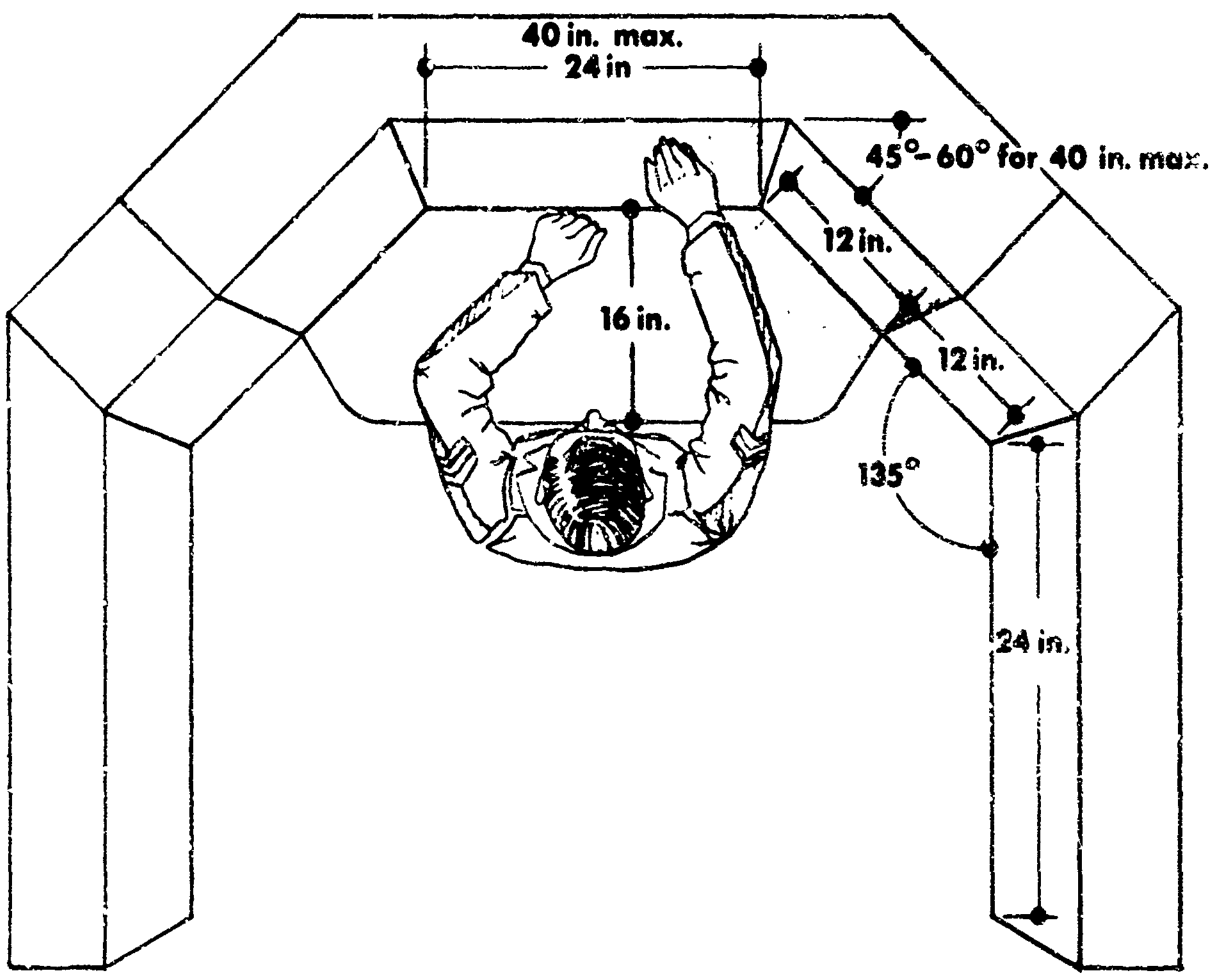


Fig. 35. Console Dimensions for Seated Operators (Wrap Around Panels)

Control Surfaces

1. In general, the control area is below the area where displays are mounted; however, displays which are closely associated with controls can be mounted on these surfaces. The control areas correspond to the optimum manual space, see Figure 29.

2. The optimum manual space is that area in which hand-operated controls can be manipulated with the greatest speed and accuracy, see Figure 29. This space is reserved for controls which must be operated frequently or are critical to operations.

3. The placement of controls in the optimum space permits:

a. Rapid and accurate identification, reaching, and activation.

b. Location of visual displays near the controls.

4. The designer should use the following principles in the layout of controls upon the console:

a. Primary controls should be located between shoulder level and waist height, see Figure 29.

b. Controls should be located so that simultaneous operation of two controls will not necessitate a crossing or interchanging of hands.

c. When controls are operated frequently they should be located to the left front or right front of the operator.

d. Frequently used controls should be grouped together, unless there are overriding reasons for separating them.

e. Frequently used controls should be located for right-hand operation.

f. Frequently used controls should be within a radius of 16" from the normal working position.

g. Occasionally used controls should be within a radius of 20".

h. Infrequently used controls should be within a radius of 28".

i. Controls should be located so that personnel can visually check their positions, regardless of the angle from which they are being viewed.

j. All controls should be within the maximum reach of the operator when seated, see Figure 29.

k. Controls requiring fine adjustments should be located closer to the operator's line of sight than controls requiring gross positioning.

l. When displays must be monitored and controls manipulated simultaneously, the controls should be placed in close proximity to and centered below that display.

m Controls that are infrequently used should be covered or placed to one side, especially if they might be inadvertently activated.

n. Occasionally used controls can be mounted behind hinged doors or recessed in the panel to prevent inadvertent actuation.

5. Where blind reach for a control may be necessary due to space constraints, the designer should note that the following will frequently occur when operators attempt to grasp a control:

a. Individuals tend to reach too low for controls located above the level of the shoulders.

b. Individuals tend to reach too far to the rear for controls located on either side.

c. Individuals tend to reach too high for controls located below the shoulder level.

Work Surfaces

1. A horizontal, or nearly horizontal, work surface is indicated in Figures 31, 32, 33, and 35. This surface serves primarily as a work or writing surface or as a support for operator convenience items, such as ash trays, etc. This surface can also be used for locating certain types of controls, e.g., joy-stick tracking control, etc.

2. When a horizontal work surface and control panel are combined, as in Figure 35, the work surface should not be more than 16 inches in depth to permit reaching the panels.

3. The minimum depth should be 10 inches in order to provide a writing surface.

Control Display Relationship

1. The placement of controls and displays on panels and consoles should be based on an analysis of operator utilization, e.g., frequency, accuracy, sequence, etc., and the importance of these controls and displays to monitoring or controlling system performance. When such an analysis has been made, a sound basis is provided for the guidelines on arrangement of controls and displays which are contained in this subsection. These guidelines are categorized in terms of:

   a. Priorities for Location of controls and displays.

   b. Spacing between controls and displays.

   c. Grouping of controls and displays by either Function or Sequence.

   d. Sequence of operation.

Location

1. Priority of location refers to the placement of the most important controls and displays in the optimum visual and manual workspaces on the panel or consoles. To establish the importance of controls and displays the following factors should be determined:

   a. Frequency and duration of use of the control or display.

   b. Accuracy and speed with which the display must be read or the control activated.

   c. Decrease in system performance and personnel or equipment safety resulting from an error or delay in using the control or display.

   d. Ease of control manipulation in various locations in terms of force, precision, and speed requirements.

2. When the above factors have been determined, the designer should apply the following principles to the design:

   a. The primary, e.g., highest priority displays and controls should be placed in the optimum visual and manual workspaces.

   b. The secondary controls and displays should be placed within the limiting areas for visual and manual workspaces so that they are readily accessible when required, e.g., emergency controls and displays which may not warrant the highest priority in location but still must be accessible if required

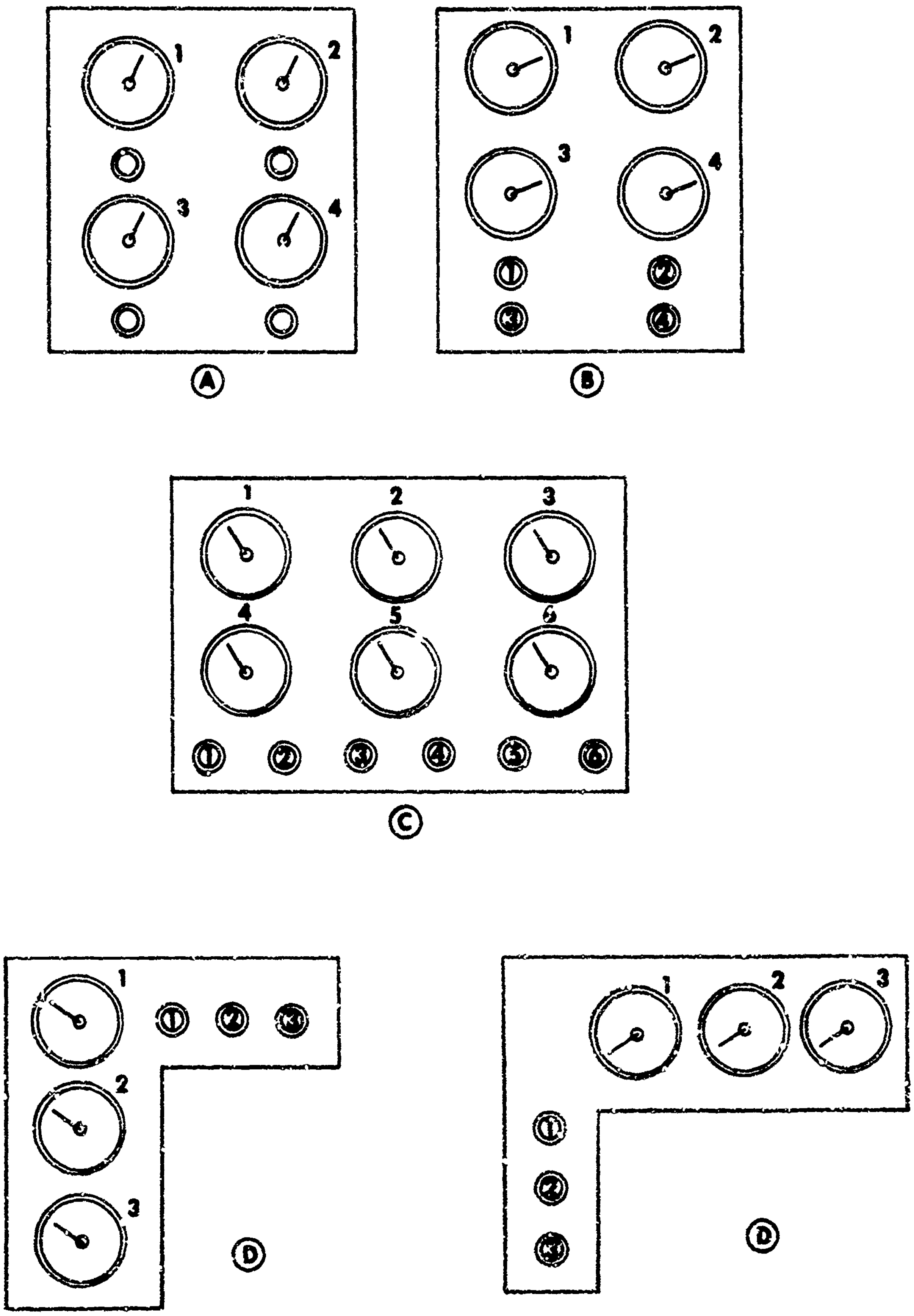


Fig. 36. Control-Display Relationship

3. The controls and displays of least importance during operation should be placed in the lowest priority positions, e.g., setup and calibration controls and displays which are not used during operation. Where controls and displays must be used by two operators, e.g., in monitoring system status, the following criteria should be applied:

a. If primary controls and displays are involved, duplicate sets should be provided wherever there is adequate space. Otherwise, controls and displays should be centered between the operators.

b. If secondary controls and displays are involved, they should be centered between the oprators if equally important to each. If the controls or displays are more important to one operator than to the other, they should be placed nearer the operator having the principal requirement for their use.

c. If direction-of-movement relationships are important, controls and displays should be located so that both operators face in the same direction.

Spacing

1. The arrangement of controls and displays should aid in the identification of the control to be used with a particular display.

2. Where a control is associated with a specific display, the control should be located so that the operator's hand does not obscure the display.

a. Each control should be located directly beneath its associated display as illustrated in (A) of Figure 36. Also, the displays should be arrayed in rows from left to right.

b. Another procedure is to locate all displays in the upper portion of the panel and all controls in the lower portion as illustrated in (B) of Figure 36. Displays and controls should both be arranged in rows from left to right on the panel. If possible, the controls should occupy the same positions relative to one another as do the corresponding displays.

c. If the controls must be arranged in fewer rows than the displays, controls affecting the top row of displays should be positioned at the far left, controls affecting the second row of displays should be placed just to the right of these, and so on as illustrated in (C) of Figure 36.

d. If a horizontal row of displays must be associated with a vertical column of controls, or vice versa, the left-most display (control) should correspond to the top control (display) as illustrated in (D) of Figure 36.

3. The spacing of controls should be based on the following considerations:

a. Requirements for the simultaneous use of controls.

b. Requirements for the sequential use of controls.

c. Body part being used.

d. Size of the control and the amount of movement required, e.g., displacement or rotation.

e. Need for blind reaching, i.e., the need to reach for and grasp the control without seeing it.

f. Effects on system performance of the inadvertent use of the wrong control.

4. When both panels are mounted at approximately the same angle relative to the operator, the relative positions of controls and displays on their respective panels should be the same.

5. When one panel is at or near the vertical and the other is at or near the horizontal, the relative positions of controls and displays should be the same.

6. Separate control and display panels should never face each other.

Functional Grouping

1. Functional grouping should be used for controls and displays which are:

a. Identical in function.

b. Used together in a specific task.

c. Related to one equipment or system component.

2. When there is no definite sequence of operation, the controls or displays should be grouped by function.

3. Functional groups of displays and their associated controls should be spatially organized so that the relationship between the function is apparent to the operator.

4. All displays that are to be used together should be placed at the same viewing distance.

5. For purposes of ready identification, noncritical functional areas or groups, e.g., those not associated with emergency operation, should be outlined by black lines, 1/16 inch wide, using color number 37038 of Federal Standard 595. Emergency or extremely critical functional areas should be set apart by a 3/16 inch red border, using color number 31136 of Federal Standard 595.

6. As an alternate method, contrasting color patches may be used to designate critical and non-critical functional areas.

Sequential Grouping

1. The following principles should be applied to displays which are observed in sequence:

   a. When displays are arranged horizontally, they should be viewed from left to right.

   b. When displays are arranged vertically, they should be viewed from top to bottom.

   c. Displays should be grouped, arranged, and located as close together as possible, providing this does not make each individual display difficult to interpret.

2. The following principles should be applied to controls which are operated sequentially:

   a. Controls used by the same hand should be arranged so that the operator moves his arm horizontally from one control to the next control.

   b. Controls which are sequentially operated by the same hand should be aligned horizontally on the panel and operated from left to right, or arranged vertically in sequence from top to bottom.

Emergency Indications

1. The method of indicating that an "emergency" condition exists in which an operator must take corrective action is of primary importance in system design. The following paragraph outlines the best concept from a human factors standpoint and should be incorporated in the design of systems where possible.

2. When an emergency condition occurs, an auditory warning signal should sound accompanied by a flashing light. The operator must acknowledge the emergency condition by silencing the auditory warning. Connected to the same control which silences the auditory warning there should be a circuit which will change the flashing light condition to a steady "ON" condition. When corrective action for the emergency condition has been successfully completed, the steady "ON" condition should return to the "OFF" or "normal" operating condition.

Auditory Warning Signals

1. Auditory warning signals to indicate the existence of a hazardous condition or conditions requiring immediate corrective action should be:

   a. Employed only in addition to a warning light.

   b. Sufficiently different from the background noises so that they may be easily recognizable.

   c. The frequency of the "Master" warning sound should be as indicated in Figure 37.

2. Where specific warning sounds are needed, the following can be readily identified as different by personnel:

   a. 1600 ± 50 cps tone interrupted at a rate of 1 to 10 cps.

   b. 900 ± 50 cps steady tone, plus 1600 ± 50 cps tone interrupted at a rate of 0 to 1 cps.

   c. 900 ± 50 cps steady tone.

d. 900 ± 30 cps steady tone, plus 400 ± 50 cps tone interrupted at a rate of 0 to 1 cps.

e. 400 ± 50 cps tone interrupted at a rate of 1 cps to 10 cps.

3. Warning signals should be of greater amplitude than the ambient noise for immediate detection and identification. That is, approximately 20 dB above threshold under noisy conditions. Signals must be kept well below 130 dB.

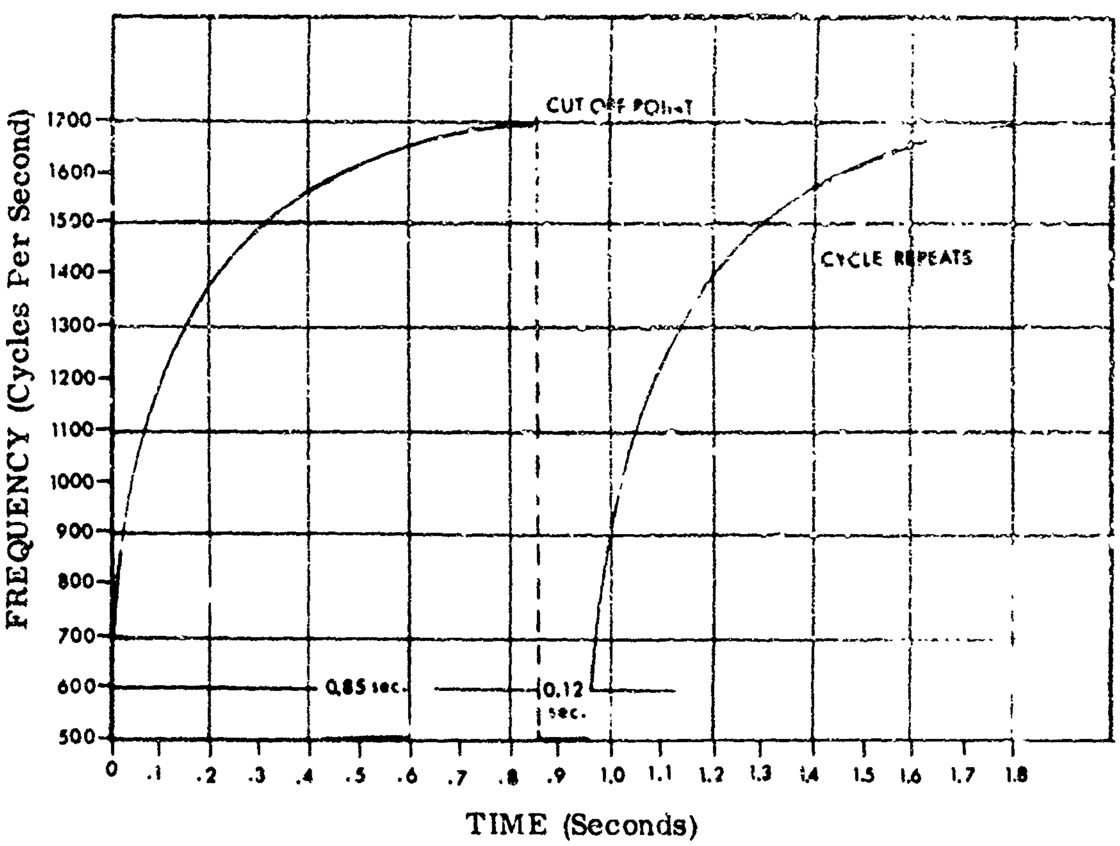


Fig. 37. Frequency Characteristics of Auditory Master Warning Signal

Visual Warning Indicators

1. The following criteria should be considered by the designer in relation to the physical characteristics and the placing in the proper location of "warning" indicators (see Fig. 28):

   a. For optimum visibility, the master warning indicator should be placed within 30° of the line of sight.

   b. Indicators used to denote an emergency situation should be visually larger than general status indicators.

   c. They should have a <u>minimum</u> brightness contrast to the immediate background of 5 to 1.

   d. They should have a <u>minimum</u> illumination intensity, when illuminated, as that of the brightest light source on the same console.

   e. The warning indicator should be colored "red" (see paragraph 1 page 138)and located not more than 60° from the line of sight.

2. Where extreme danger to personnel or equipment exists, the warning indicator should be flashing red and:

   a. Flash at a rate of 3 to 5 pulses per second.

   b. Have flashing "ON" time approximately equal to "OFF" time.

   c. Should be such that when the "flashing" device fails, the light comes on steadily.

   d. Should provide "word" warning whenever possible, but "word" warning indicators should be placed within 10° of the standard line of sight.

   e. Where a symbol, instead of a word, is used, the indicator should be placed within 30° of the standard line of sight.

CONTROLS

General

1. It is important to consider two basic factors in the design or selection of control devices:

   a. The compatibility between the movement or location of the control and the unit to be controlled.

   b. The efficiency with which the operator can utilize the control and display combinations.

2. Controls may be categorized on the basis of whether the action is discrete or continuous:

   a. Discrete action controls can be set at any one of a limited number of fixed positions.

   b. Continuous action controls can be set at any position between the limits of movement of the control.

3. All controls should be designed, oriented, and located so they are in accordance with normal work habit patterns, customary reactions, and human reflexes. There are certain stereotyped relationships between controls and displays that should be provided to minimize error, see Table 15.

4. The direction of movement of the control should be consistent with the movement of the controlled object or moving portion of the display.

5. Controls should be distributed so that no one limb will be overburdened.

6. The most important controls may not be the most frequently used controls, therefore, the criticality of the control must also be considered.

7. Controls used for performing the same function for different but closely associated equipment should be consistent in size and shape.

TABLE 15

CONVENTIONAL CONTROL MOVEMENTS

Function	Control Action
On	Up, right, forward, clockwise, pull
Off	Down, left, rearward, counterclockwise, push
Right	Clockwise, right
Left	Counterclockwise, left
Raise	Up
Lower	Down
Retract	Up, rearward, pull
Extend	Down, forward, push
Increase	Forward, up, right, clockwise
Decrease	Rearward, down, left, counterclockwise

8. Controls should have the following information located on the panel or control:

a. The identification of the control function.

b. The method of operation, if it is not readily identifiable.

9. Controls should be easily identifiable by the visual or tactile senses and should be clearly distinguishable from each other by color, size, shape or location.

10. The use of one control should not interfere with the use of another control unless they are purposely interlocked in sequence.

Selection Considerations

1. In selecting the proper control, the designer should determine the following:

   a. The function of the control, its purpose and importance to the system, the nature of the controlled object, the type of change to be accomplished and the extent, direction, and rate of change.

   b. The task requirements in terms of the precision, speed, range and force requirements in using the control and the effect on the system of reducing one of these requirements in order to improve another.

   c. The informational needs of the operator including the operator's requirements for locating and identifying the control, determining the control position and sensing any change in control position.

   d. The workplace requirements in terms of the amount and location of available space in which to place the control and the importance of locating the control in a certain position to assure proper grouping or association with other equipment controls and displays.

2. Hand-operated controls should be used for rapid or precise adjustments.

3. When performance requirements are such that the controlled object can be adjusted in a limited number of discrete steps, discrete adjustment (detent) controls should be used rather than continuous adjustment (non-detent) controls.

4. Controls may be combined as an aid in sequential or simultaneous operation, to reduce reaching movements, or to economize on panel space. However, the possibility of accidental activation should be minimized.

5. Controls requiring large or continuous forward application of force should be foot operated. Whenever possible, not more than two controls, of even the simplest type, should be assigned to each foot.

6. When force and range of settings are the primary consideration in control selection, use the control recommended in Table 16.

TABLE 16

RECOMMENDED MANUAL CONTROLS

Control Function	Control Type
Small Actuation Force Controls	
2 Discrete Positions	Key Lock Push Button Toggle Switch Legend Switch
3 Discrete Positions	Rotary Selector Switch Toggle Switch
4 to 24 Discrete Positions	Rotary Selector Switch
Continuous Setting (linear and less than 360°)	Continuous Rotary Knob Joystick or Lever
Continuous Slewing and Fine Adjustment	Crank Continuous Rotary Knob
Large Actuation Force Controls	
2 Discrete Positions	Foot Push Button Hand Push Button Detent Lever
3 to 24 Discrete Positions	Detent Lever Rotary Selector Switch
Continuous Setting (linear and less than 360°)	Handwheel Joystick or Lever Crank Two Axis Grip Handle
Continuous Setting (more than 360°)	Crank Handwheel Valve Two Axis Grip Handle
Elevation Setting	Crank Handwheel Joystick or Lever Two Axis Grip Handle

Design Characteristics

1. Control design characteristics are described in Figures 38 through 47.

2. Control selection is not to be construed as limited to the controls shown in this section. The illustrations contained herein are representative examples whose purpose is to show recommended dimensions.

Hand Crank

1. Handle shape should allow the maximum amount of contact with the surface of the hand.

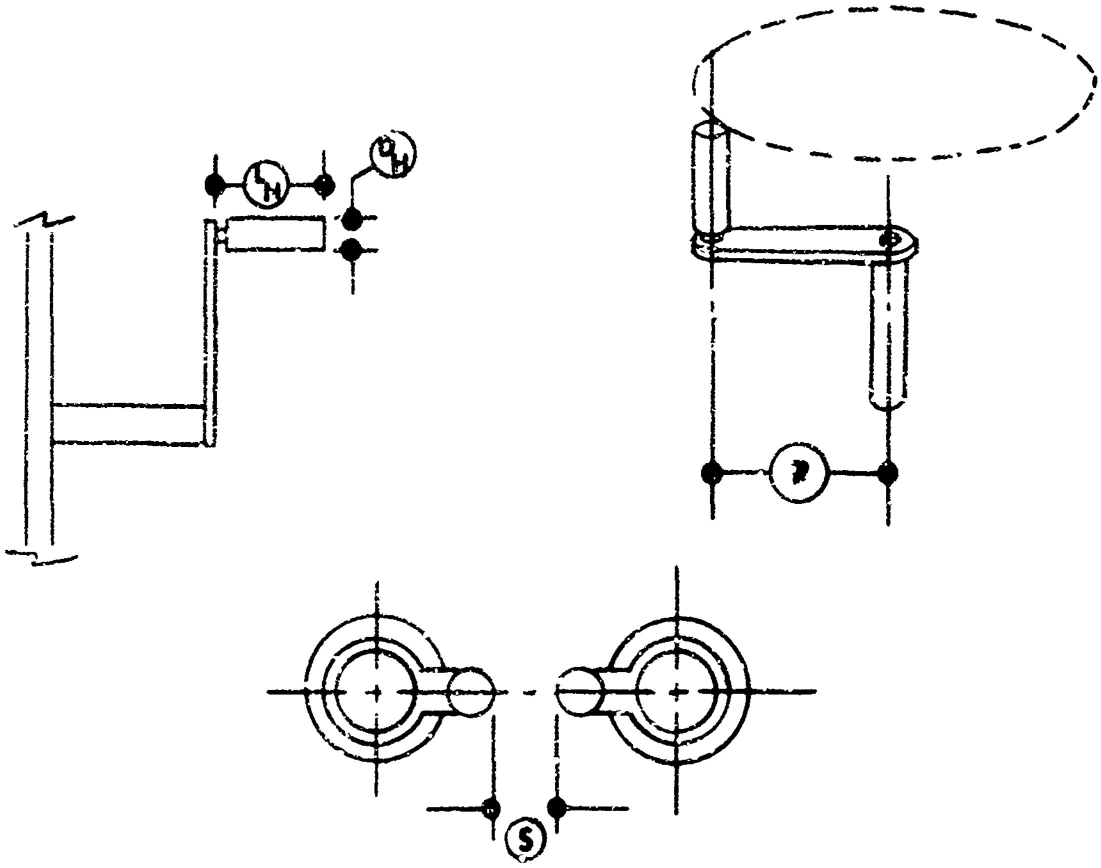
2. The handle should turn freely about its shaft.

3. Location should be between 36-48 inches above the floor for the standing operator.

4. If the ratio of fast-to-slow crank operating speed is greater than 2 to 1, the operator should have the choice of two gear ratios.

5. Spacing between outside edge of crank handle and any obstruction should be at least 3 inches.

6. Cranks which are to be turned rapidly should be mounted so that the turning axis lies within the range from perpendicular to through 60° from, the frontal plane of the body.



RPM*	D_H HANDLE (Diameter)	L_H HANDLE (Length)	R (Radius) Min.	R (Radius) Max.	S Separation Min.	S Separation Max.	Resistance Min.	Resistance Max.
None	1.0"	3.75"	9.0"	16"	3"	--	2 lb.	50 lb.
175	1.0"	3.75"	5.0"	8.0"	3"	--	6 lb.	15 lb.
275 (max.)	0.5"	1.5"	0.5"	4.5"	3"	--	2 lb.	5 lb.

* Revolutions per minute required of personnel.

Fig. 38. Cranks

Handwheels

1. Handwheels requiring constant two-hand operation should be restricted to a 120 degree arc displacement.

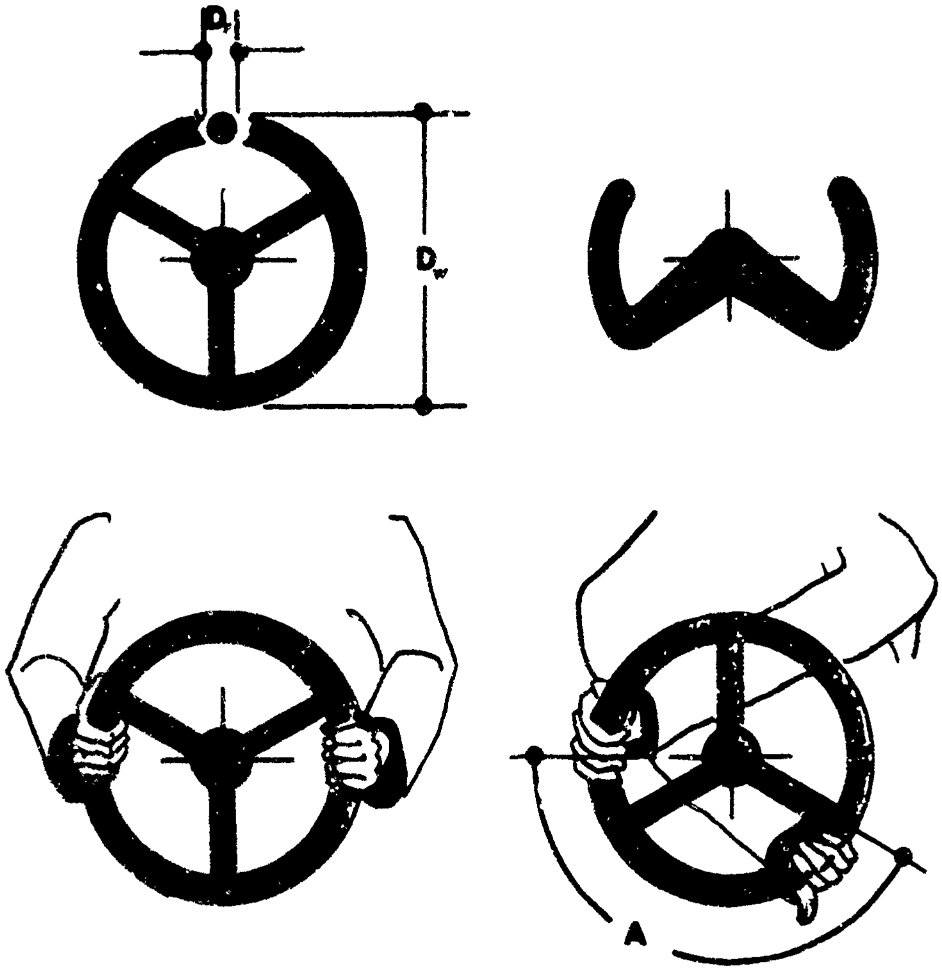
2. The gripping surface should be indented or knurled to aid in grasping.

3. Handwheels should rotate clockwise for on, right or increase and counter-clockwise for off, left or decrease.

4. Where multiple rotation is not required and the handwheel interferes with the visual field, that portion of the handwheel not needed for firm hand grasp may be cut away.

5. A valve handle is a special case of a knob or a handwheel.

6. All valve handles should be clearly labeled in accordance with the function performed in addition to the direction of movement.



	D_W (Wheel Diameter) *	**	D_r (Rim Diameter) *	**	A (Displacement) *	**	(Resistance) *	**
Minimum	2.0"	7.0"	0.75"	0.75"	--	--	5 lb.	5 lb.
Maximum	4.25"	21.0"	2.0"	2.0"	--	120 deg	30 lb.	50 lb.

* One-hand operation.
** Two-hand operation.

Fig. 39. Handwheels

Key Operated Switch

1. Keys should be shaped so the proper method of insertion is obvious to the operator.

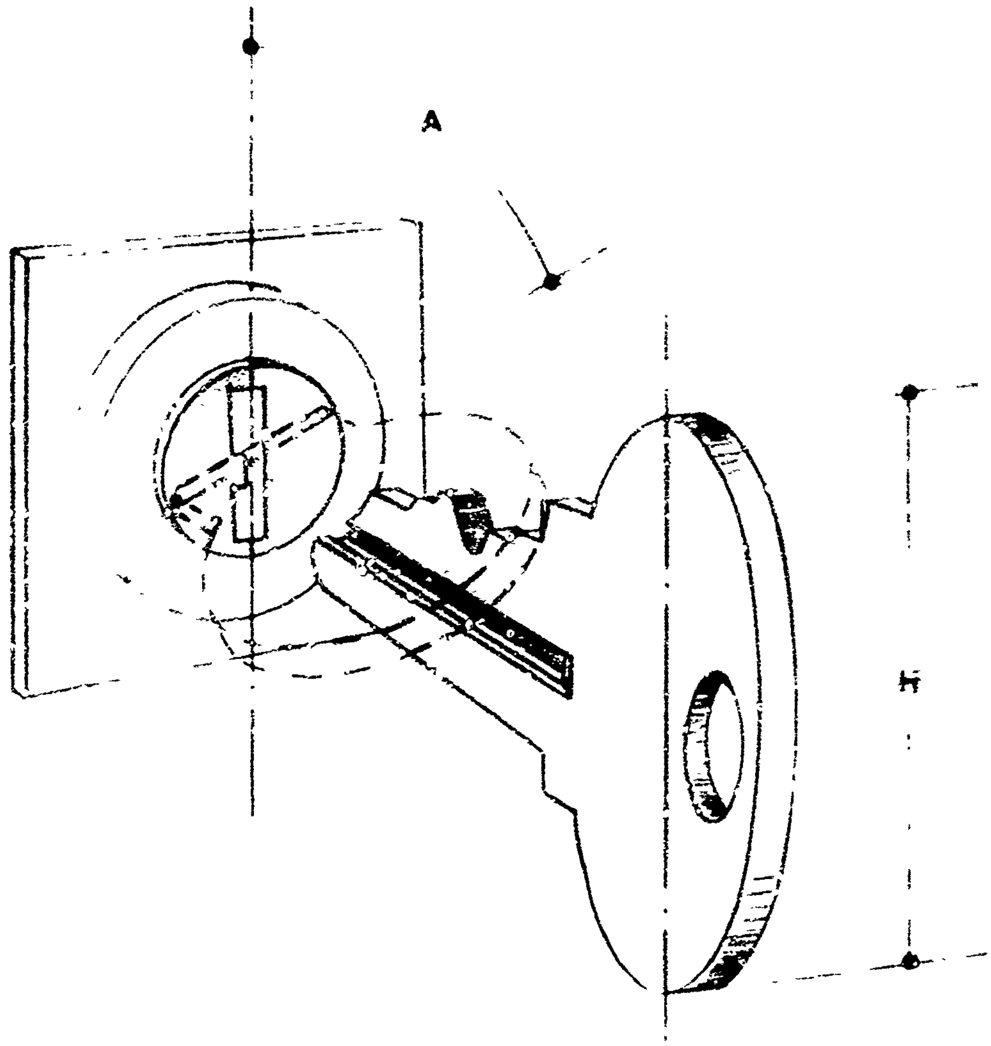
2. Locks should be oriented such that the vertical position is the off position.

3. Keys should be retained in the lock in all positions but the off position.

4. Keys which have a single row of teeth should be inserted in the lock with the teeth pointing in the UP or forward position.

5. Keys which have teeth on both edges should be coded to insure proper insertion in the lock.

6. "On" and "off" positions should be labeled.



	A (Displacement)	H (Height)	Resistance
Minimum	30°	0.5"	12 oz.
Maximum	90°	3.0"	48 oz.

Fig. 40. Key-Operated Switch

Knobs

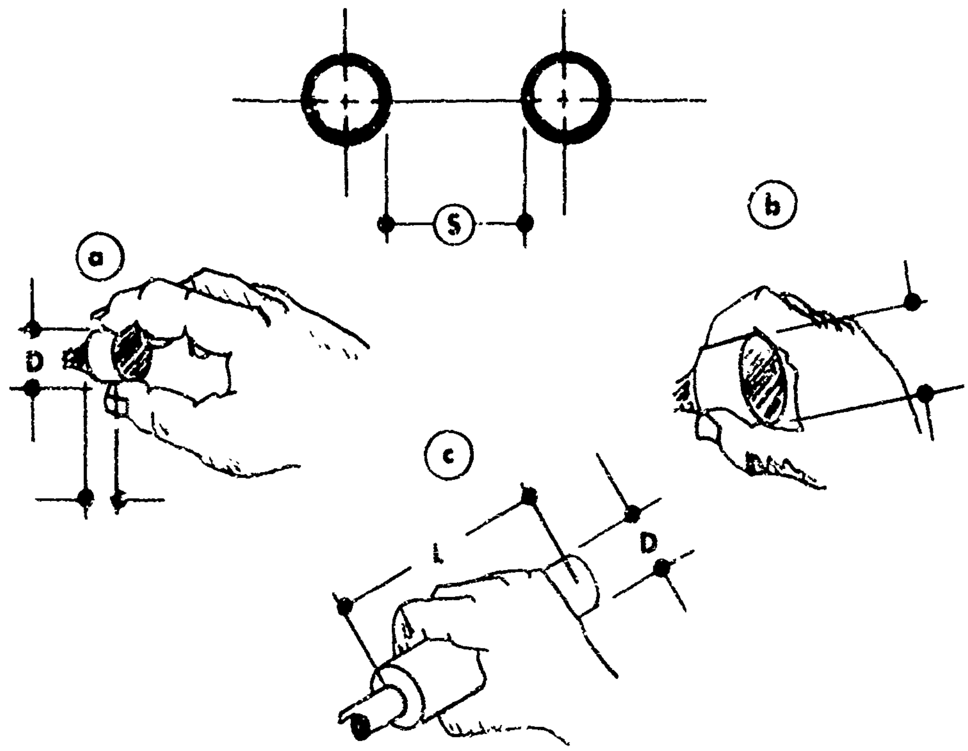
1. Knob diameter should increase with the force required for control operation. The smaller knobs should be used for coarse adjustments.

2. Knobs should be serrated or knurled to prevent slipping.

3. The knurling and serrating of knobs should be such that if the shaft sticks, the operator is not likely to cause physical damage to his hands.

4. Knobs which perform the same function should have the same shape.

5. Resistance should be large enough so that inadvertent touching or outside forces will not change the setting.



	(a) Fingertip Grasp		(b) Thumb & Finger Encircled	(c) Palm Grasp	
	H (Height)	D (Diam.)	D (Diameter)	D (Diam.)	L (Length)
Minimum	0.5"	0.375"	1.0"	1.5"	3.0"
Maximum	1.0"	4.0"	3.0"	3.0"	--

	S (Separation)		Torque	
	One Hand Individually	Two Hands Simultaneously	*	**
Minimum	1"	3"	--	--
Optimum	2"	5"	--	--
Maximum	--	--	4.5 in. oz.	6.0 in. oz.

* To and including 1.0" diameter knobs. ** Greater than 1.0" diameter knobs.

Fig. 41. Knobs

Legend Switch

1. Legend switches may be used for, but not necessarily limited to, the following conditions:

   a. To display qualitative information which requires the operator's attention to an important system status.

   b. Where minimal interpretation by the operator is required.

   c. When functional grouping or a matrix of control switches and indicators is required and minimal space is available.

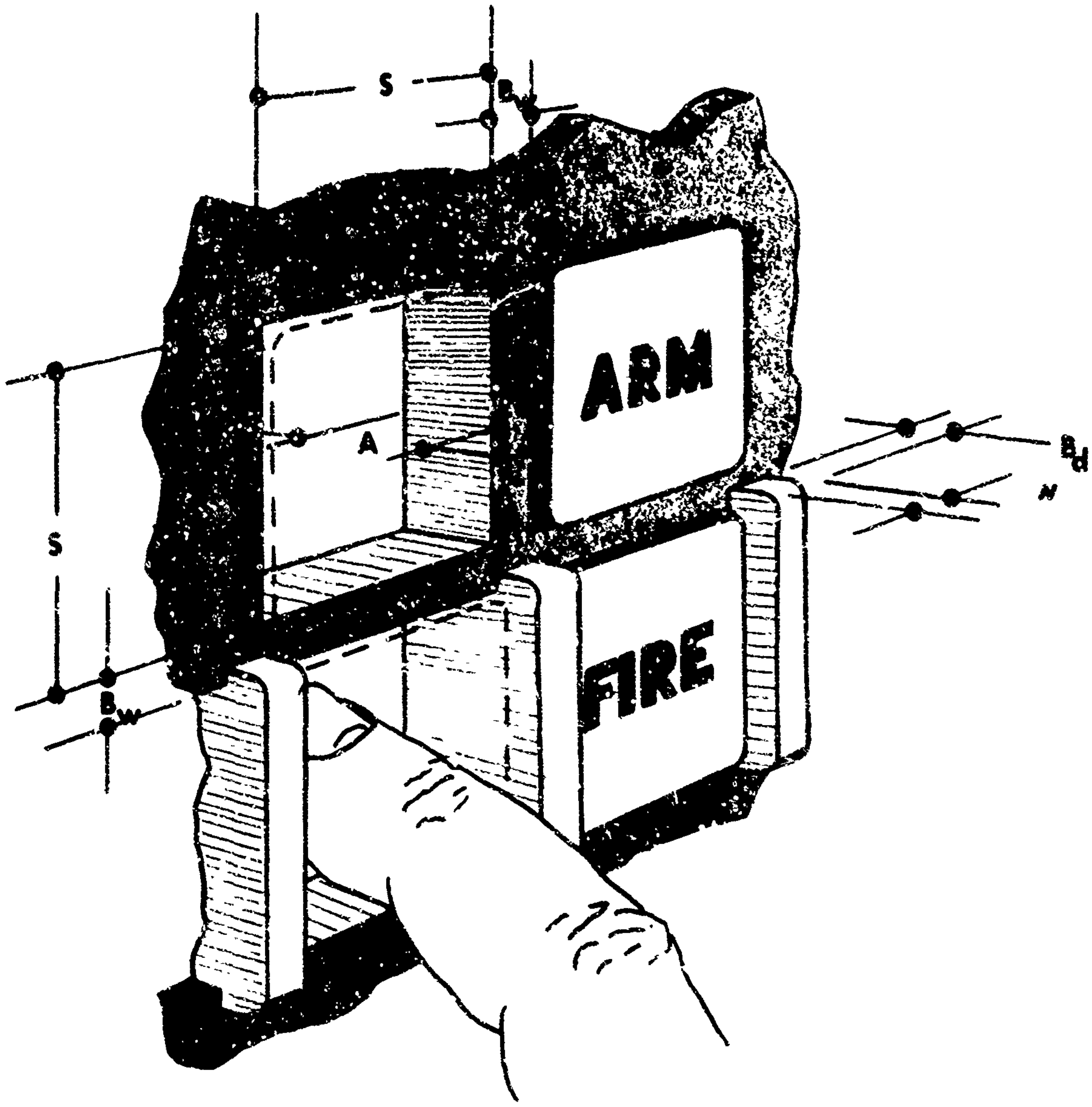
2. The location of legend switches should be restricted to a 30° cone along the normal line of sight from the operator's position.

3. For positive indication of switch activation, the legend switch should be provided with a detent or click.

4. Lamps within the legend switch should be replaceable from the front.

5. The legend should be legible when only one lamp is operating within the switch.

6. Where the legend switch does not contain dual bulbs, the legend switch circuit should be provided with a lamp test capability.



	S (Size)	A (Displacement)	Barriers* B_W	B_d	Resistance
Minimum	3/4"	1/8"	1/8"	3/16"	10 oz.
Maximum	1-1/2"	1/4"	1/4"	1/4"	45 oz.

* Barriers will have rounded edges.

Fig. 42. Legend Switch

Lever/Joystick

1. Levers mounted on and perpendicular to the floor should have their handles located between the waist and shoulder height of the operator.

2. Levers parallel to the floor should have the hand grips located 28 inches above the floor for the standing operator to be able to exert the greatest lifting force.

3. Lever should be pushed when accuracy is a requirement.

4. When rapid operation of a lever mounted in front of the operator is a requirement, a fore-and-aft direction should be used.

5. When large force is required and the lever must move in a lateral direction, the largest force can be obtained by the right hand pushing toward the left.

6. When grouped levers in front of the operator pivot about a common axis, or relatively close axes, they should move in a fore-and-aft direction.

7. For the seated operator the maximum push or pull of the lever is obtained with the elbow at 135°, hand grip at about elbow height and the lever moving in a vertical plane passing through the shoulder joint.

8. Detent pressure should be provided on discrete position levers.

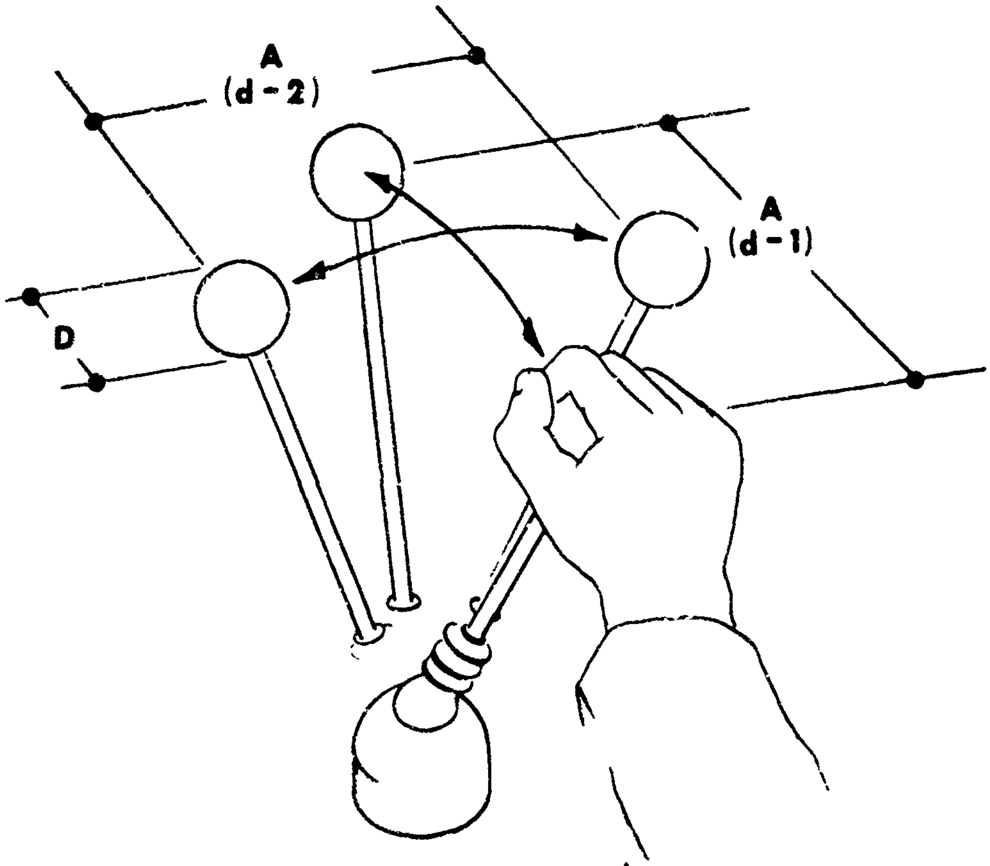
9. When fine adjustments are made with small levers (e.g., joysticks) the following should be provided:

    a. Elbow support for large hand movements.

    b. Forearm support for small hand movements.

    c. Wrist support for precise finger movements.

10. For joystick controls, the optimum condition for setting tolerance of 1/10 inch is 2 1/2 units of stick movement to 1 unit of indicator movement.



	D (Diameter)		A (Displacement)		Resistance (d-1)		Resistance (d-2)	
	Finger Grasp	Hand Grasp	(d-1) (Forward)	(d-2) (Lateral)	Using one Hand	Using two Hands	Using one Hand	Using two Hands
Minimum	0.5"	1.5"	--	--	2 lb.	2 lb.	2 lb.	2 lb.
Maximum	3.0"	3.0"	14"	38"	30 lb.	50 lb.	20 lb.	30 lb.

Fig. 43. Lever/Joystick

Pedals

1. Where the application of a great deal of force and displacement is required, the foot pedal should be used as a control device.

2. Two major types of pedal action are:

   a. Translatory, which permits movement in one direction with a spring loaded return. Only a relatively limited amount of translatory displacement is possible.

   b. Reciprocating, in which two pedals move in opposite directions about a longitudinal axis.

3. Pedals should be designed to utilize normal limb action, e.g., the foot and entire leg.

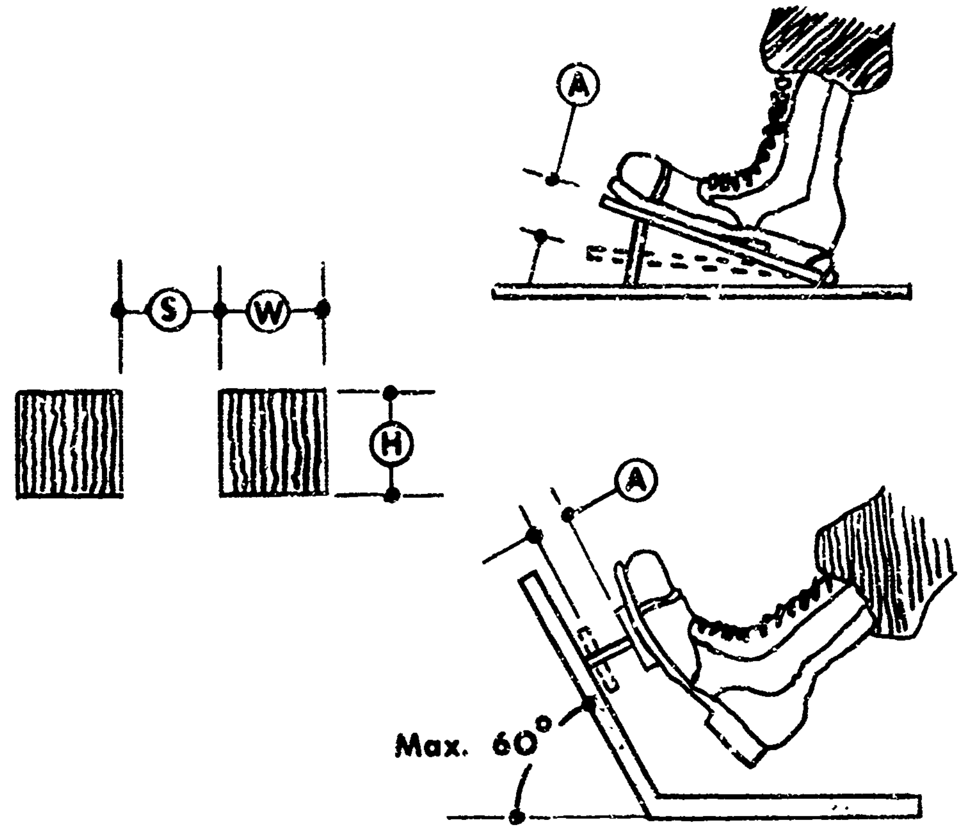
4. Spring tension should support the weight of the foot resting on the pedal prior to force application.

5. The motion of the operator's leg should not require delicate or complex movements but should, instead, be simple and direct.

6. A non-skid surface should be provided on the face of the pedal and on the heel plate where applicable.

7. The separation between pedals, Figure 44, is a function of the maximum pedal width used. As the pedal width increases the pedal separation may be decreased proportionately.

8. Where pedals are mounted near side walls or other obstructions the minimum separation between the pedal centerline and the wall or obstruction should be 5.0 inches.



	H Height	W Width	S Separation	A Displacement: Normal Operation	With Heavy Boots	Ankle Flexion	Total Leg Movement
Min.	1.0"	3.0"	4.0"	0.5"	1.0"	1.0"	1.0"
Max.	--	--	--	2.5"	2.5"	2.5"	7.0"

	Resistance: Foot not resting on pedal	Foot resting on pedal	Ankle Flexion only	Total leg Movement
Min.	4.0 lbs.	10 lbs.	10 lbs.	10 lbs.
Max.	20.0 lbs.	20 lbs.	20 lbs.	180 lbs.

Fig. 44. Pedals

Push Buttons

1. A definite feel and audible click should be provided to indicate that the push button is activated.

2. Push buttons should have an elastic resistance that gradually increases and then suddenly drops to indicate that the control has been activated.

3. When push buttons are activated, there should be a definite feedback of the equipment response to the operator either by a visual indicator or an auditory response.

4. Push button surface should be concave to fit the shape of the finger.

5. The following methods should be considered for the safeguarding of accidental activation of hand or finger operated push buttons:

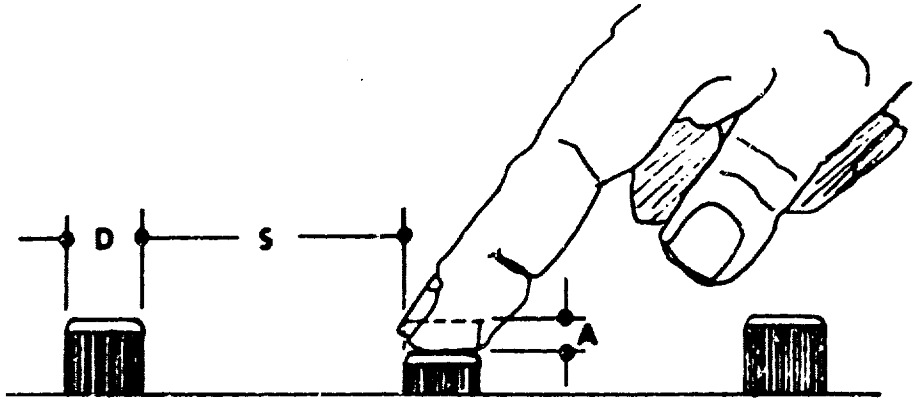
   a. Using channel or cover guards.

   b. Flush mounting.

   c. Recess mounting.

   d. Mechanical or electro-mechanical interlocks.

   e. Button guards.

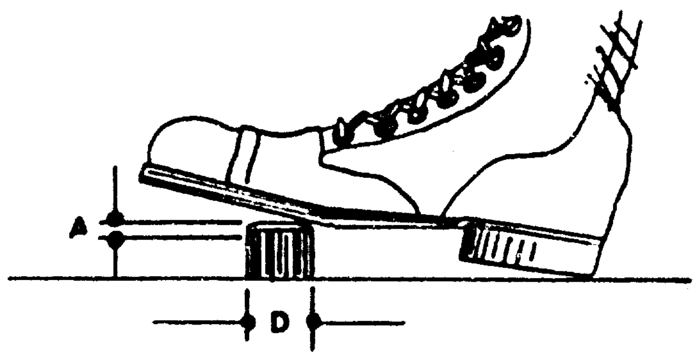


Hand Push Button

	D (Diameter) Fingertip Operation	D (Diameter) Thumb or Heel of Hand Operation	A (Displacement) Thumb or Finger Operation	Resistance Fingertip Operation	Resistance Little Finger Operation
Minimum	0.375"	0.75"	0.125"	10.0 oz.	5.0 oz.
Maximum	0.75"	--	1.500"	40.0 oz.	20.0 oz.

S (Push Button Separation)

	Single finger operation	Single finger sequential operation	Operation by several fingers
Minimum	0.50"	0.25"	0.50"



Foot Push Button

	D (Diameter)	A (Displacement) Normal Operation	A (Displacement) Heavy boot Operation	A (Displacement) Ankle flexion only	A (Displacement) Total leg movement	Resistance Foot will not rest on control	Resistance Foot will rest on control
Minimum	0.50"	0.50"	1.00"	1.0"	1.0"	4.0 lbs.	10.0 lbs.
Maximum	--	2.5"	2.5"	2.50"	4.00"	20.0 lbs.	20.0 lbs.

Fig. 45. Push Buttons

Rotary Selector Switch

1. Rotary selector switches should not have two positions, of those available, that are 180 degrees from each other.

2. Switch positions should be no closer than 15 degrees.

3. Maximum separation between switch positions should be 45 degrees.

4. When non-visual positioning is required, positions should be no closer than 30 degrees.

5. Switches should be designed so that detent stops offer enough resistance to movement so that settings can be made by touch alone.

6. No more than 24 positions should be incorporated in one rotary control.

7. Stops should be provided at the beginning and end of the range of control positions, where it is not intended that the selector switch be used for continuous sequencing through 360°.

8. Clockwise rotation of a selector switch should result in a numerical or alphabetical increase of the scale associated with it.

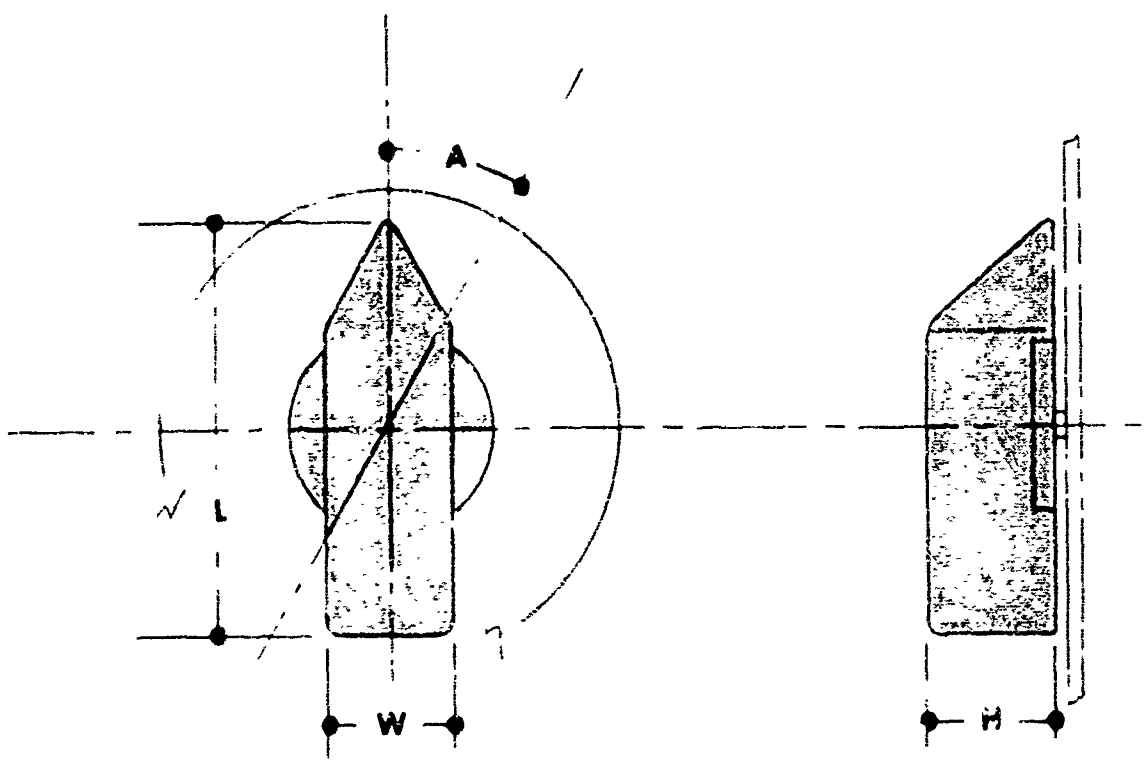
9. It should not be possible for a rotary selector switch to remain fixed between positions.

10. Rotary selector switches should use a moving pointer knob with a fixed scale.

11. Moving pointer should be bar-shaped with parallel sides and the index end should be tapered to a point.

12. Position of the pointer knob in relation to the scale should be such as to minimize parallax between pointer index and scale marking.

13. Resistance of the selector switch (Fig. 46) should be measured at the tip.



	L (Length)	W (Width)	H (Depth)	A (Displacement) *	**	Resistance
Minimum	1.0"	--	0.5"	15^{o}	30^{o}	12 oz.
Maximum	4.0"	1.0"	3.0"	45^{o}	45^{o}	48 oz.

* Visual Positioning
** Non-visual Positioning

Fig. 46. Rotary Selector Switch

Toggle Switches

1. Toggle switches should have flip-type operation and snap-action contact.

2. When toggle switches are used in momentary contact situations, they should be spring-loaded to the off or neutral position.

3. Toggle switches should be accompanied by a pilot light to indicate circuit status where other displays do not provide a positive indication.

4. Toggle switches should be vertically oriented. 'Toggle switches should be "on" in the up position.

5. When the toggle switch is oriented horizontally, the "on" position should be to the right.

6. When an indicator light is used with the toggle switch, it should be located so that activation movement of the switch arm is toward the indicator.

7. Toggle switches should be guarded against accidental activation.

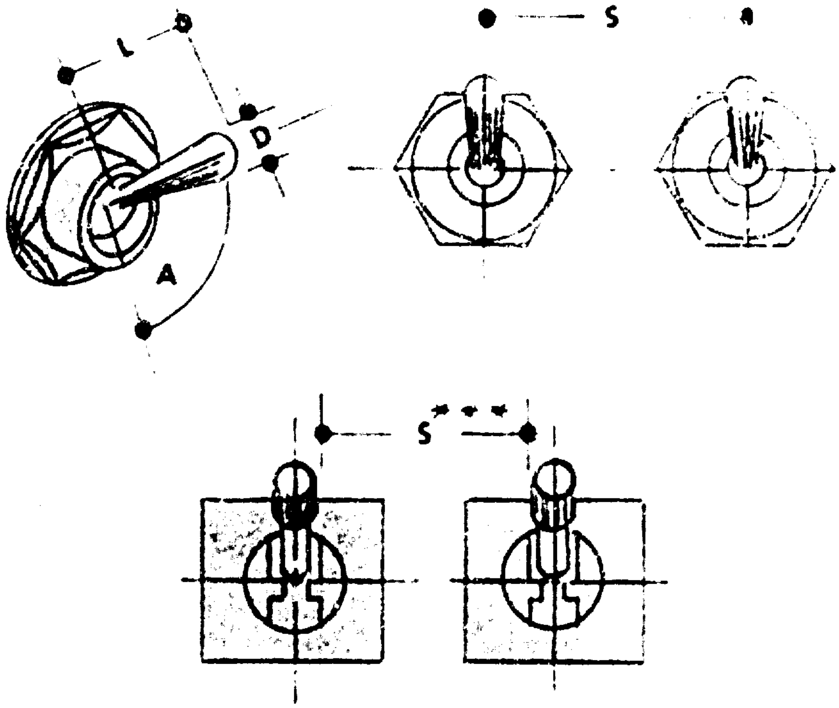
8. Toggle switch resistance should increase slowly until contact is made, and then drop to zero as the switch snaps into position except for momentary contact switches.

9. It should not be possible for toggle switches to stop between positions.

10. Where there is a severe space limitation, a three-position toggle switch may be used in place of a rotary selector switch.

11. The use of a three-position toggle switch should be restricted to non-critical system functions.

12. A three-position toggle switch should be used as a momentary control and should snap back into the off or neutral position when not manually controlled.



	A (Displacement)	L (Arm Length) *	L (Arm Length) **	D (Control Tip Dimension)	(Resistance) Small Switch	(Resistance) Large Switch
Minimum	30°	0.5"	1.5"	0.125"	10 oz.	10 oz.
Maximum	120°	2.0"	2.0"	1.0"	16 oz.	40 oz.

S (Toggle Switch Separation)

	Single Finger Operation	Single Finger Operation ***	Single Finger Sequential Operation	Simultaneous Operation by Different Fingers
Minimum	0.75"	1.0"	0.5"	0.625"
Optimum	2.0"	2.0"	1.0"	0.75"

* Use by bare finger.
** Use by gloved finger.
*** Using a lever lock toggle switch.

Fig. 47. Toggle Switches

c. The increase of numerical progression should read clockwise, from left to right, or from the bottom up.

d. Whole numbers should be used in numbering major graduation marks, except where measurements are normally expressed in decimals.

e. The number of minor or intermediate marks should not be greater than nine, fewer if possible.

f. Optimum visual contrast should be provided between scale face and markings.

g. On stationary scales, all numbers should be oriented upright.

h. On moving scales, all numbers should be oriented to be upright at the reading position.

i. The display should be designed to that the control or display pointer will just meet, but not overlap, the shortest graduation marks.

j. To minimize parallax, the pointer should be mounted as close as possible to the face of the dial.

k. All displays should be constructed, arranged, or mounted so as to minimize the reflectance of ambient illumination from the glass or plastic display cover. This is especially important when panels are inclined from the vertical away from operator.

l. Wherever feasible, linear scales should be used in preference to non-linear scales.

5. Displays should be designed so that the failure of the display or display circuitry will be immediately or readily apparent to the operator.

6. Failure of display circuitry should not cause a failure in the equipment associated with the display.

Selection Considerations

1. For maximum efficiency in operation, dials, scales, gages, or meters should be selected for the following situations:

a. To indicate direction of movement or orientation in space.

b. To distinguish increasing or decreasing trend of the values measured by the instrument.

c. When only an approximate reading is important.

d. For check reading rather than continuous monitoring.

2. Direct-reading counters should be used for the following conditions:

a. For rapid and accurate reading of stationary or slowly changing quantitative information.

b. As an indication of revolutions in multirevolution indicators.

c. When economy of panel space is important.

3. Cathode-ray tubes should be used in the following situations:

a. Continuous-monitoring activities.

b. To monitor direction of movement of another object, as in radar.

c. To monitor or check-read frequency or amplitude waves, as in sampling the output of a radar transmitter.

4. Lights should be used in the following situations:

a. For qualitative go-no-go indicators, on-off indicators, malfunction indicators, emergency warning lights (use flashing signals), inoperative-equipment indicators, caution indicators, and indicators for operability of separate components.

b. As warm-up indicators.

5. Auditory displays (buzzers, bells, etc.) should be used for the following situations:

a. As an emergency or warning device.

b. When the immediate reaction of the operator is important.

6. Auditory displays should be used with, or as alternatives to, lights in the following situations:

a. When environmental-lighting conditions are such that lights might not be easily detected.

b. When the operator will be occupied monitoring lights, dials, counters, etc.

c. When multiple signals (warning, emergency, malfunction) are needed.

d. When extreme redundance is required.

Design Characteristics

Cathode Ray Tube

1. The visibility, or probability of detection, of cathode ray tube signals depends upon five visual factors:

a. The size, in visual angle, of the pip or signal.

b. The brightness of the background, including noise and clutter.

c. The brightness of the pip.

d. The length of time the signal is present.

e. The state of adaptation of the eye.

2. Whenever possible the scope face should be mounted perpendicular to the operator's line of sight. However, space for the equipment and personnel, and special lighting conditions may necessitate viewing the scope obliquely. Since oblique viewing of the scope would reduce the visual angle of the signal, there would be a resultant loss in visibility for threshold targets. The scope may be tilted 30^{o} from the standard line of sight position without noticeably affecting the detection of weak signals.

3. Twelve inches is a recommended viewing distance for prevention of visual fatigue, however, shorter viewing distances increase the visual angle subtended by signals and visibility can be improved by close viewing. Therefore, if periods of scope observation are short, and where it is important that dim signals be detected, the recommended 12-inch viewing distance can be reduced to 6 inches for short periods when checking very small or very dim signals.

4. When plotting is not required, a 5 to 7 inch scope diameter is adequate.

5. Where plotting or viewing by more than one operator is a requirement, a 10 to 12 inch scope diameter should be provided.

6. Small scopes of 2 to 5 inch diameter should be used for infrequent calibration or tuning purpose only.

7. The shape of the bezel or frame around the scope should be dictated by the type of presentation. Use a round frame for a PPI presentation and a rectangular frame for an A-scan presentation.

Radar Display Symbology

General

1. The presentation of a radar display can be enhanced when a symbolic shape code is used in association with, or in place of a pip.

2. The basic principles in accordance with technical feasibility to be followed in the selection of a symbolic code are:

   a. Number of categories -- The number of discrete symbols used to provide information in symbolic form should be held to a minimum. The minimum number of categories required for a specific application must be determined early in the research and development cycle.

   b. Minimum information -- A symbol type should be selected whereby a single meaning is attached to the symbol for use in all systems.

   c. Absolute identification -- Observers must be able to read code symbols without any reference to comparison standards. This type of readout requires absolute recognition of a symbol standing alone rather than relative discrimination of a symbol in contrast with another.

   d. Combination codes -- If more information must be displayed than can be provided by any one coding symbol, or if more than one type of information is to be provided by a single symbol, then a combination code may be used. The respective symbols must be capable of being read out separately without confusion.

   e. Ease of learning -- The code system must be capable of being learned easily and its interpretation should not be affected by emergencies or adverse conditions.

   f. Symbol-readout compatibility -- The symbol and the event symbolized should have a natural relation. Their association should conform to well established habits or population stereotypes.

   g. Size -- Symbols should be large enough for good legibility and small enough to fit on a screen without clutter or interference with readout of other information.

Radar Display Coding

1. There are numerous techniques available for coding information. Information coding maximizes the amount of information that can be displayed in the space available.

2. Coding dimensions that may be used are:

   a. Numerals and letters

   b. Geometrics

   c. Color

   d. Flicker

   e. Brightness

   f. Line length

   g. Inclination

   h. Ellipse

   i. Blip diameter

   j. Visual number (dot series)

   k. Compound codes

Numerals and Letters

1. Alpha-numerics should subtend a visual angle of at least five minutes (1/40 inch high symbols read at a 15 inch viewing distance). Where the viewing distance will exceed or be less than 15 inches multiply viewing distance in inches by .0017 and round to three numbers to determine optimum symbol size.

2. Symbols should be oriented to appear in an upright position.

3. Symbols should be about 1/2 inch high and have a strokewidth 1/8 to 1/10 of the height. If smaller symbols must be used the strokewidth to height ratio must be 1:10 or less. Strokewidth must be no less than 0.02 inch and no more than 0.14 inch.

4. Standard numerals (MIL-M-18012) should be used.

5. Of all symbolic numerals, those derived from an eight-element straight line matrix are read most easily.

6. Standard letters (MS 33558) should be used.

7. Lower case letters are confused more readily than upper case and should be avoided.

8. t/l, v/w, c/o, m/n are confusing letters and should be avoided.

9. Q/O, 1/I, 8/B, 2/Z, 5/S are numeral-letter confusions and should be avoided.

Geometrics

1. The circle, rectangle, cross and triangle are the most distinctive geometric forms.

2. Squares, polygons and ellipses are poor in discriminability and should be avoided.

3. Variations of a single geometric form, such as sets of round, pointed and triangular characters, should be avoided.

4. Unique symbols, e.g., swastika, anchor, flag, rocket, airplane, are good for use in specific situations.

5. The number of symbols should be kept small and under adverse display conditions should not exceed six.

6. Stroke width/height ratios of 1:8 to 1:10, and symbols 0.4 inch or larger are best for viewing up to seven feet.

7. A symbol should comply with the conventional stereotyped meanings normally associated with such symbols.

Color

1. Color is best used in combination with alpha-numerics or geometrics.

2. Color presents excellent possibilities for an easily discriminable code but the difficulty in generating distinct color signals at this time precludes its use in many CRT displays.

Flicker

1. Flicker is excellent as an attention getting device and should be reserved for use in emergency situations only.

2. Three flicker rates should be the limit in any practical situation. These rates are 4/sec; 1/sec; or 20/min. assuming a 50 percent on-off ratio.

3. Flicker causes eye fatigue and is annoying to watch, thus it is an undesirable coding technique for other than alerting or similar situations requiring immediate attention of the operator.

Brightness

1. More than two brightness levels (high and low) are detrimental to performance.

Line Length

1. Four line lengths can be identified without error.

Inclination

1. Many variations are possible in combination with other codes.

2. Training is necessary for accuracy.

3. Inclinations of 0^{o}, 90^{o}, 180^{o} and 270^{o} can be identified accurately. Inclinations of 45^{o}, 135^{o}, 225^{o} and 315^{o} may be used if larger alphabet is required.

4. Line length should be between 0.2 and 0.3 inches.

Ellipse

1. Ellipses offer a poor coding technique.

2. Three ellipse sizes are most practical for display purposes, where ellipses only are displayed.

Blip Diameter

1. Three blip diameters are the practical limit for display purposes.

Visual Number Coding (generated by a series or group of dots)

1. This technique is detrimental to performance.

2. No more than six dots should be used to form the group or series.

Compound Coding

1. No more than two symbols should be combined where rapid, accurate use of the symbology is required.

2. No auxiliary symbol should cross, distort, interfere with or in any way obscure the primary symbol.

3. When other information is required, it should be in the form of numerical representation or in actual numbers or letters.

4. The geometric center of the symbol and/or a large clear dot should indicate location.

Meanings of Coding Technique

1. Certain code symbols have stereotyped meanings and should be used with those meanings.

  a. Straight line angular forms generally indicate hostile vehicles.

  b. Rounded forms generally indicate friendly vehicles.

  c. Crossed lines are generally used to indicate a fixed or reference point.

  d. An arrow points in the direction of travel.

  e. Size or numerosity indicates magnitude.

f. Red stands for danger or emergency.

g. A flickering symbol indicates emergency.

h. Location is at the geometric center of the symbol or at a dot.

TABLE 17

MINIMUM SATISFACTORY SIZES FOR VISUAL SYMBOLS

Symbol	Dimension	Viewing Conditions* Good	Average	Poor
Spots & circles	Diameter			
Squares Rectangles	Length of side Length of shorter side	0.02"	0.06"	0.30"
Lines	Width	0.005" (for bright line on dark background) 0.01" (for dark line on bright background)	0.02" (recommended as minimum for radar use)	0.05"

* Definition of Viewing Conditions

Good: Brightness high (10 or more millilamberts)
Brightness contrast high (90% or more)
Viewing distance short (not more than 3 feet)

Average: Intermediate between good and poor conditions.

Poor: Brightness low (5 or less millilamberts)
Brightness contrast poor (50% or less)
Vewing distance long (up to 20 feet)

TABLE 18

SUMMARY TABLE OF CODING METHODS FOR SYMBOLS

CODE	NUMBER OF STEPS IN CODE	EVALUATION	COMMENTS
Alpha-numerics	Unlimited	Excellent	High information handling rate. Unlimited number of coding steps.
Geometrics	20 or more	Excellent	Certain shapes easily recognized. Many coding steps.
Color	4	Excellent	Difficulty in techniques of reproducing for CRT. Objects easily and quickly identified.
Flicker	5	Poor	Distracting and fatiguing. Interacts poorly with other codes. Best for attention getting. Few steps in code.
Brightness	3	Poor	Limited number of steps. Fatiguing. Detrimental to decoding performance.
Line Lengths	4	Fair	Limited number of steps. Will clutter display.
Angular Orientation	12	Fair	95% of estimates will be in error less than 15^{o}.
Inclination	24 or more	Fair	Many coding steps, especially with combinations.

TABLE 18 Continued

CODE	NUMBER OF STEPS IN CODE	EVALUATION	COMMENTS
Ellipse	7 or fewer	Poor	Few steps. Found inferior for information handling.
Blip Diameter	5 or fewer	Poor	Few steps. Noise on display interferes.
Visual Number	6	Fair	Few steps.
Combinations	Unlimited	Good	Care must be used to prevent overloading symbols with too much information. Detrimental to quick performance.

Counters

1. Counters should be used for presenting large ranges of quantitative data where continuous trend indication is not required but where quick precise reading is required.

2. The numbers should change by snap action in preference to continuous movement. Odometer and hour meters are exceptions to snap action numeral change.

3. Counters should be mounted as close to the panel surface as possible to maximize viewing angle and minimize parallax and shadows.

4. Numbers should not follow each other faster than about 2 per second if the operator is expected to read the numbers consecutively.

5. Counters used to indicate sequencing of equipment should be designed to reset automatically upon completion of the sequence. Manual provision for resetting should also be provided.

6. The rotation of the counter reset knob should be clockwise to increase the counter indication or to reset the counter.

7. Table 19 shows the counter character dimensions that should be used for different operator viewing distance and under different illumination levels.

TABLE 19

COUNTER CHARACTER DIMENSIONS FOR OPERATOR VIEWING DISTANCE

Viewing Distance	Height*	Width	Stroke Width	Minimum Separation Between Numerals
		Normal Illumination (Above 1 ft.L)		
28 in.	0.15	0.15	0.037	0.025
36 in.	0.19	0.19	0.032	0.032
60 in.	0.31	0.31	0.052	0.052
		(Low Illumination (0.03 to 1.00 ft. L)		
28 in.	0.22	0.22	0.037	0.037
36 in.	0.28	0.28	0.047	0.047
60 in.	0.50	0.50	0.084	0.084

*For reading distances less than 28 in., minimum character height should be not less than 0.125 in.

Flags

1. Flags may be used to display qualitative non-emergency conditions.

2. Flags should be in high contrast with the background.

3. Flags should operate by snap action.

4. Flags should be as close to the surface of the panel as possible.

5. When flags are used to indicate the malfunction of a visual display, the "malfunction position" of the flag should at least partially obscure the operator's view of the malfunctioning display, and should be readily apparent to the operator under all expected levels of illumination.

6. Provisions should be made to test proper operation of the flags.

Indicator Lights

General

1. Transilluminated indicators currently used are of two general types, simple indicator lights (e.g., pilot lights, bull's-eye lights, jewel light, etc.) and single and multiple legend indicator lights. Legend lights present information in the form of meaningful words, numbers, symbols or abbreviations.

Color Coding

1. Red, green, yellow, blue and white colors should be in accordance with Type I, Aviation colors of MIL-C-25050.

  a. Green -- Green should indicate satisfactory operation of equipment, e.g., in tolerance, test OK, read, etc. In general, green should indicate that a system function is operating or has operated successfully.

  b. White - White should indicate such items as status, alternative functions and selection mode, test in progress, or any other similar items that imply neither success nor failure of system conditions.

  c. Yellow -- Yellow should alert an operator to situations where caution, recheck, or delay is necessary.

d. Red -- Red should be used to alert an operator that a situation exists which makes the system inoperative, e.g., error, no-go, failure, malfunction.

e. Blue -- Blue should be used only when a fifth color is necessary. No specific meaning is attached to the color.

Flash Code

1. Flashing red -- Flashing red should be used to indicate an extreme danger to equipment or personnel. Flash rate should be within 3-5 flashes per second with approximately equal amount of "on" and "off" time.

2. Flashing white -- Flashing white should be used as an alerting signal on communications call boards.

Simple Indicator Lights

1. Transilluminated indicators should be used to display qualitative information to the operator. They should be used primarily to display information that requires either an immediate reaction on the part of the operator, or to call his attention to an important system status. They may occasionally be used for maintenance and adjustment purposes.

2. When indicator lights having a single bulb are installed on a control panel, a master light test control should be incorporated. Panels containing three or less lights may be designed for press-to-test bulb testing.

3. Where a panel contains single and dual bulb indicators, the master light test control should test both types.

4. A malfunction should be indicated by a malfunction indication, not by the mere absence of an operating condition signal.

5. Lights should not be used solely to indicate control position unless the control position is not, or cannot be made apparent by proper design and labeling of the control. Lights should be used to display equipment response and not merely control position.

6. When a control is associated with a transilluminated indicator, the indicator light should be so located as to be immediately and unambiguously associated with the control. In most instances the light should be located above the control.

7. When used under varied ambient illumination, a dimming control with limited range should be provided. The range of the dimming control should be so limited at the lower adjustment that the lights will still be visible under the brightest expected ambient illumination.

8. For critical functions, the indicator should be located within 30 degrees of the normal line of sight. Warning lights should be integral with, or adjacent to, the lever, switch, or other control device by which the operator is to take action.

9. Master caution, master warning and summing lights used to indicate the condition of the entire subsystem should be set apart from, and be larger than, the lights which show the status of the subsystem components.

Legend Lights

1. The number of legend lights should be kept to a practical minimum, while fulfilling information feedback requirements.

2. A legend light should illuminate immediately upon the occurrence of the event described by its legend; it should go out upon the termination of the event described by its legend.

3. A legend light should be used to provide qualitative information; normally, it should not give a command. If a command must be given, the legend should clearly and unambiguously indicate that this is the case.

4. Legend lights having excessively small frontal areas should be avoided. Ample frontal area should be available for lettering commensurate with the anticipated legend requirements.

5. The legend face should not be significantly recessed into its housing.

6. The possibility of legend loss or interchange should be minimized by such techniques as captive legends, coded keyways, etc.

7. Illumination of the mounted legend light should not result in light leakage.

8. Legend light indications for malfunction isolation purposes should be provided only down to the point dictated by the system maintenance philosophy.

9. Legend lights should operate in a fail-safe fashion. Failure of a legend light or its indicator circuit should not influence or cause failure of its monitored circuits and equipment.

10. Lamps should be provided that incorporate filament redundancy or dual bulbs. That is, when one filament or bulb fails, the second remains illuminated. The decreased intensity of the light indicates the need for lamp replacement.

11. Optimum visual contrast should be provided between the legend lettering and its background.

12. Trademarks, company names, or other similar markings not related to the information displayed to the operator should not appear on the face of the light.

Plotters

1. Plotters are recommended for use when a visual record of continuous graphic data is desired.

2. The plotting point should be readily visible and not obstructed by the pen assembly and arm.

3. The plotted function should provide optimum contrast with the background on which it is drawn.

4. A take-up provision should be made for plotting materials when necessary.

5. When an operator is required to interpret graphic data, aids such as overlays should be provided. Overlays should not obscure or distort the data.

Printers

1. The guidelines considered here in relation to printers pertain primarily to the printout or hard copy produced by such devices.

2. Hard finish matte paper should be used to avoid the problems of smudged copy and glare.

3. Paper hold-downs should be provided to reduce paper vibration.

4. Accordion-fold paper should be used, particularly if record search is required.

5. A take-up provision for finished copy should be available.

6. A paper advance control should be provided to enable the operator to read the most recently printed line.

7. A cutting edge should be provided to permit rapid, even removal of printed material.

8. An indication of the paper supply remaining should be provided.

9. Instructions for reloading of paper, ribbon, ink, etc., should be contained in an instruction plate attached to the printer.

10. Provision should be made for the loading of paper or ribbon without extensive disassembly or the use of special tools.

11. Storage should be provided for a spare paper, ribbon, ink, etc., supply.

12. Black lettering should be used on white paper to provide maximum contrast.

Scalar Indicators

General

1. Before a designer selects a scale for a mechanical indicator he should decide on the appropriate scale range and should study the operator's task to determine the precision required of the instrument reading.

2. Scales should be designed to that interpolation between graduation marks is not necessary. However, when space is limited it is better to require interpolated readings than to clutter the dial with crowded graduation marks.

3. A scale that is to be read to the nearest 1, 10, or 100 pounds of pressure, etc., should be selected from those scales with graduation interval values of 1, 10, or 100. If accuracy to the nearest .5, 5, or 50 units or .2, 2, or 20 units is required, scales with the appropriate graduation interval values should be selected.

4. Scales numbered by intervals of 1, 10, 100 etc., and subdivided by ten graduation intervals are superior to other acceptable scales.

5. Some combinations of graduation interval values and scale numbering systems are more satisfactory than others. Table 20 will assist in the selection of the most readable scales.

6. For recommended scale dimensions, see Figure 48.

7. The pointer position of a scalar indicator should be at twelve o'clock for right-left directional information, and at nine o'clock for up-down information. For purely quantitative information either position may be used.

TABLE 20

SCALE NUMERICAL PROGRESSION

Good					Fair					Poor			
1	2	3	4	5	2	[illegible]	6	8	10	0	2.5	5	7.5
5	10	15	20	25	20	40	60	80	100	4	8	12	16
10	20	30	40	50	200	400	600	800	1000	0	15	30	45
50	100	150	200	250						30	60	90	120
100	200	300	400	500						0	60	120	180

8. If the display is used for setting, such as tuning in a desired wavelength, it is usually advisable to cover the unused portion of the dial face. The open window should be large enough to permit at least one numbered graduation to appear at each side of any setting.

9. If the display is used in tracking, as in the case of heading indicators, the whole dial face should be exposed.

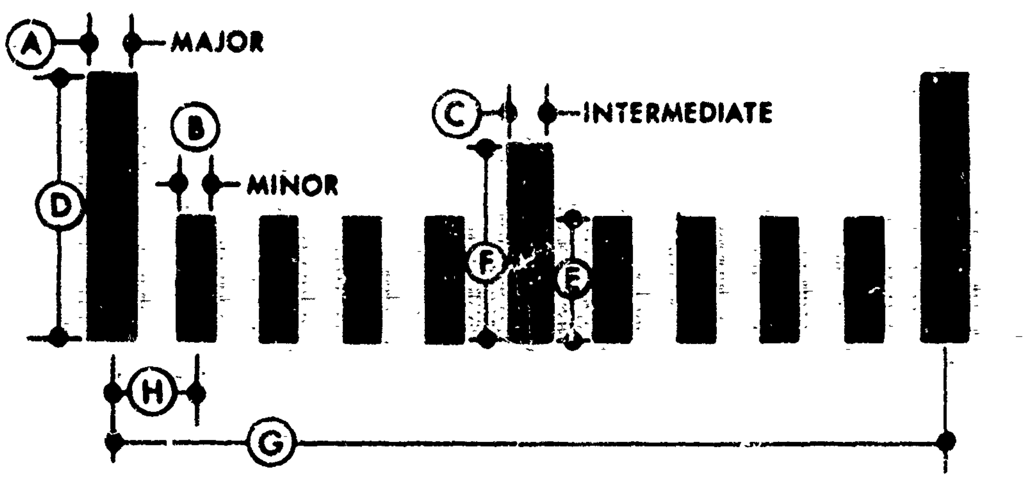
Moving Pointer Fixed Scale Indicators

1. Circular Scales should be designed as follows:

   a. Clockwise movement of the pointer should increase the magnitude of the reading to be in keeping with the operator's expectations.

   b. In cases where positive and negative values around a zero are being displayed, the zero should be located at the nine or twelve o'clock position. The positive values should increase with clockwise movement of the pointer and the negative values increase with counterclockwise movement.

   c. In general it is better to place the numerals inside of the graduation marks to avoid constriction of the scale and hiding of numbers by the bezel. If space is not limited the numbers may be placed outside of the marks to avoid having the numbers covered by the pointer.



Dimension (in inches)	Viewing Distance 28 in.	36 in.	60 in.
A (Major index width)	0.035"	0.045"	0.075"
B (Minor index width)	0.025"	0.032"	0.054"
C (Intermediate index width)	0.030"	0.039"	0.064"
D (Major index height)	0.220"	0.283"	0.471"
E (Minor index height)	0.100"	0.129"	0.214"
F (Intermediate index width)	0.160"	0.206"	0.343"
G (Major index separation between midpoints)	0.700"	0.900"	1.500"
H (Minor index separation between midpoints)	0.070"	0.090"	0.150"

Fig. 48. Scale Markings

2. Vertical and Horizontal Straight Scales should be designed as follows:

a. The pointer should move up or to the right to indicate an increase in magnitude.

b. The numbers should be located on the side of the graduation marks opposite the pointer. The graduation marks should be aligned on the side of the pointer and stepped on the side of the numbers.

c. The pointer should be to the right of vertical scales and at the bottom of horizontal scales.

Moving Scale Fixed Pointer Indicators

Circular Scales

1. There exist certain ambiguities with moving circular scales and the associated control movement; thus Moving Scale Fixed Pointer Indicators are not recommended for use. One of the following three principles of human engineering must be violated in the design of circular moving scales:

a. Principle 1 - Scale numbers should increase in a clockwise direction around the dial. Values on moving circular scales, therefore, increase with counterclockwise rotation of the dial face.

b. Principle 2 - The direction of movement of the associated control should be compatible with the direction of movement of the dial, e.g., clockwise movement of the control should result in clockwise movement of the dial.

c. Principle 3 - Clockwise movement of a control should result in an increase in function.

2. If principle 1 is compromised, e.g., clockwise movement of the control results in counterclockwise movement of the dial, operators err in the initial direction of turn. If principle 3 is compromised, a standardized control movement-system relationship is violated.

3. The following recommended practices in the design and use of circular moving scales will minimize the effects of these incompatibilities:

a. The numbers should progress in magnitude in a clockwise direction around the dial face. Therefore, counterclockwise movement of the dial face increases the readings.

b. If the associated control has no direct effect on the behavior of the equipment, e.g., tuning in radio stations, etc., the scale should rotate counterclockwise (increase) with counterclockwise movement of the associated knob or crank.

c. If the associated control has a direct effect on the behavior of the equipment, e.g., speed, direction, etc., the scale should rotate counterclockwise (increase) with a clockwise, upward movement or movement to the right of the associated control.

Vertical and Horizontal Moving Straight Scales

1. The same direction-of-motion ambiguities exist as in circular moving scales. The numbers should increase from bottom to top or from left to right.

2. The scale should move down or to the left (increase) when the associated knob or crank is moved clockwise, or when the associated lever is moved upward, or to the right.

3. See also the recommendations for straight scales with moving pointers.

4. It is acceptable to deviate from the previously listed scale design principles when other primary considerations must be met. Certain unique applications of scales require other design features, and compromises with the principles listed previously must be made.

5. An azimuth indicator with the numerical progression of 30, 60, 90, etc., is less satisfactory than those previously recommended. However, this represents a compromise between the best numbering progression and a manageable size of dial. Where the azimuth indicator is a small dial, the numbered cardinal points, e.g., north, east, south, and west, serve as anchoring points in the interpretation of this indication and a progression by 30's is a good solution. Where the dial can be made large enough, the major intervals should be marked by 10's.

6. Nonlinear scales condense a large range into a relatively small space and yet permit sensitive readings at certain critical ranges of the scale. In situations where error tolerances are a constant percentage of the indication, a logarithmic scale is very suitable. However, logarithmic scales should contain as many numbered graduation marks as possible, to minimize errors as a result of linear reading habits.

Pointers

1. Full visibility pointers on scalar indicators should be provided with a fine tip having a long taper that starts at the center of the dial.

2. The pointer tip should be the same width as the width of the smallest graduation mark.

3. For vertical and horizontal straight scalar indicators, where the exposed portion of the pointers is restricted by the rectangular configuration of the display, a flag, spade or target pointer should be used.

4. Pointers should be located to the right on vertical scales and at the bottom on horizontal scales.

5. Pointers should have a maximum distance between pointer and scale graduation mark of 1/16 inch.

6. The angle subtended between the tip of the pointer and the plane upon which the scale is located should be a maximum of 20°.

7. Pointer should meet but not overlap the shortest scale graduation mark.

8. Pointer should not cover completely the scale numbers.

9. Pointer should be the same color as the numbers and scale divisions.

10. There should be no more than two pointers on a single shaft.

11. Reciprocal pointer ends should be easily distinguishable.

LABELING

General Requirements

1. For ease of locating, reading or manipulating, labeling should be used for identification. The type of labeling may be determined by a number of factors such as:

   a. Accuracy of identification required.

   b. Time available for recognition.

   c. The distance at which the labels will be read.

   d. The illumination level and its color characteristics.

2. The selection and design of labels should conform to the following principles:

   a. A label should describe to the user the information needed to perform his task.

   b. Labels should be located in a consistent manner throughout the equipment.

   c. Labels should be composed of familiar words, that is, not too technical or difficult.

   d. Wording should be as brief as possible, omitting punctuation.

   e. Labels should be read horizontally, not vertically.

   f. Labeling should be supplemented where necessary by other coding procedures such as color and shape.

   g. Labels should be easily seen and not covered or obscured by other units in the assembly.

   h. Labels should be large enough to be easily read at the expected operator reading distance.

   i. Generally, labeling should be done in capital letters, however, where labels contain several long lines of printing, upper and lower case letters should be used.

j. The use of bold face letters should be restricted to short words or phrases requiring emphasis.

k. Labels should be placed very near to, or on, the item to eliminate any source of confusion with other items and labels.

l. Labeling should be etched or embossed into the surface for durability, rather than stamped, stenciled, or printed. Decals are an acceptable but less desirable method.

Numeral and Letter Design

Style

1. Any one of the type fonts listed in Table 21 may be selected for labeling. However, when one type font has been selected it should be used consistently for labeling throughout the system.

TABLE 21

RECOMMENDED TYPE FONTS

Type Font	Type Font
Airport Bold Condensed	Futura Demi-Bold
Airport Demi-Bold	Futura Medium
Airport Medium Condensed	Futura Bold
Airport Semi-Bold	Groton Condensed
Alternate Gothic #2	Lining Gothic #66
Alternate Gothic #3	Spartan Heavy
Alternate Gothic #51	Spartan Medium
Alternate Gothic #77	Tempo Bold
Franklin Gothic Condensed	Vogue Medium

Height to Stroke Width Ratio

1. Where panel lables are illuminated by ambient or local illumination the height to stroke width ratio should be within the range 6:1 to 8:1.

2. For transilluminated markings or labels on panel surfaces the height to stroke width ratio should be within the range 10:1 to 12:1. When dark adaptation is a requirement, transilluminated markings or labels may appear excessively bright and will reduce character legibility. Under dark adaptation conditions the height to stroke width ratio should be between 12:1 and 20:1.

Width

1. The average width of characters should be between 65% and 85% of their height.

2. The letters I, M, W, and the numerals 1 and 4 may vary from the average width. The geometric proportions for these characters are determined by the type font.

Spacing and Size*

1. Letters and numerals should be so spaced that the area between adjacent characters is equal.

2. The spacing between groups of letters and numerals should be equal to the average character width of the type face used.

3. Spacing between lines of characters should be equal to the height of the capital characters. Where space constraints exist, the height of the lower case character should be used as the spacing between lines.

4. The following character sizes should be used for the labeling indicated, based on 28 inch viewing distance:

   a. Console or Panel Title Character size - 1/4 inch

   b. Subdivision Title Character size - 3/16 inch

   c. Component Title Character size - 1/8 inch

*Type size in points does not describe the character size desired, i.e., 9 point is 1/8 inch but this is total type block, not necessarily character size. The actual character size may vary from manufacturer to manufacturer for 9 point type.

5. Where the viewing distance from the normal operating position will exceed 28 inches, the character size of the Component Title should be increased to the values shown in Table 22, and the other title character sizes should be increased proportionately.

TABLE 22

CHARACTER SIZE AND VIEWING DISTANCE

Distance (inches)	Type Size (inches)
29 to 43	3/16
44 to 55	1/4
56 to 72	3/8

6. Component labeling should be centrally located 1/8 inch above the component (see preferred viewing area, Fig. 28). Where space is a constraint, the label should be placed to the right of the component 1/8 inch from the edge and read horizontally.

7. Manufacturer's identification should not be displayed on the front of a console or panel in a manner which may distract the operator or interfere with the visual task.

Content

1. Labels should be brief, but not so cryptic as to be ambiguous or confusing.

2. Common words or words that are readily understood and ordinarily used by the operator should be used on labels. Technical words should be used only when they are necessary to impart exact information and it can be expected that the operator will have a working knowledge of them.

3. Abbreviations and symbols should be avoided if possible. Where space constraints exist causing the need for the use of abbreviations, MIL-STD-12 is suggested as a guide. Where symbols are used, they should be meaningful and in common usage.

Labeling for Identification

Assemblies

1. Each assembly should be labeled with a clearly visible, readable, and meaningful name or sign to increase operator efficiency. To accomplish this, the assembly label should:

   a. Specify the overall system of which the assembly is a part.

   b. Include the assembly's popular name and function.

   c. Include a stock number for requisition purposes.

   d. Be located in such a position that it is not obscured by adjacent assemblies.

   e. Be located on the flattest, most uncluttered surface available.

   f. Be located on a main chassis of the assembly.

   g. Be located so as to prevent accidental removal, obstruction, or handling damage.

Access Openings

1. Each access opening should be labeled with:

   a. Its precise function.

   b. Nomenclature indicating the specific items accessible through it.

   c. Nomenclature indicating the auxiliary equipment which will be used through it.

   d. Schedule time periods for accomplishing servicing or maintenance operations.

2. Where screw adjustments may be made through access openings, "line-up" markings should be included to indicate the proper orientation for insertion of the adjustment tool.

3. If any information needed at an access opening cannot be presented due to space limitations, the access opening should have a coded (color, shape, size) label referring to the appropriate operating or maintenance manual.

Connectors

1. Each permanently installed receptacle should have a label indicating type of output and the appropriate connector. The label should be adjacent to the receptacle, aperture or connector to aid in clear identification.

Instruction Plates

1. Instruction plates should be as brief as possible without distorting the intended meaning.

2. Instructions should be listed in a step-by-step manner rather than contained in a continuous running paragraph.

3. Instruction plates should be permanently attached to the applicable item.

4. The print should be engraved such that the instructions can be read when the marking paint, etc., has chipped or worn away.

Lift Points

1. Lift or hoist points should be clearly marked and accompanied by weight or stress limitations.

2. Lift or hoist point labels should be located on the body member at the point of lift, rather than on a removable item located on the body member, e.g., protective cover, access covers, etc., that may become separated from the point of lift.

Test Points

1. Each test point should be labeled to aid in ready recognition.

2. Nomenclature should be unique for every point in order to establish a simple means of cross reference to pertinent manuals.

3. The manuals and, where possible, the test point labels, should contain precise indications of the function and expected reading that can be tested at each point.

Safety Hazards

1. Wherever hazards to personnel or equipment cannot be eliminated by design, a visual warning of the condition should be prominently displayed. Safety labels should be brief and uncluttered. Generally, they should consist of not more than two or three words.

CODING

General

1. Coding is used to aid in the identification of controls, indicators, connectors and other devices that perform the same function or are consistently used together. Coding is frequently employed to make various unrelated devices readily distinguishable from each other.

2. There are many methods of coding available to the designer; however, the method or methods selected should be consistent in meaning throughout the system.

3. When deciding upon the type of coding to use in a particular situation, the designer should consider the following factors:

   a. The types of coding already in use.

   b. Kinds of information to be coded.

   c. The nature of the tasks to be performed and the conditions under which the tasks will be performed.

   d. The number of coding categories available within each coding method, e.g., the number of different knob shapes available.

   e. Space and illumination required for the various coding methods.

   f. The need for redundant or combination coding.

   g. The standardization of coding methods.

Controls

Color

1. With the exception of emergency controls, color coding of controls should be held to a minimum or applied very conservatively.

2. Color coding of controls should be used only when vision is unrestricted and when the level of ambient illumination is sufficient to permit reliable color discrimination.

3. For important and frequently used controls, the color selected should have high spectral visibility in order to attract operator attention and minimize search time.

4. The colors selected for critical controls should be in sharp contrast to those selected for noncritical controls.

5. The colors used should differ considerably among themselves.

6. Where related controls and displays are color coded, they should be coded the same color.

Shape

1. Functional shapes which suggest the purpose of the control should be used.

2. All shapes used in a particular application should be sufficiently different from each other to avoid confusion. A combination of shapes that cannot be readily discriminated visually should not be used.

3. Controls used for a similar purpose or function should be the same shape.

4. When the control must be distinguished by touch alone, the minimum dimensions of the shape selected for inclusion on the control should be:

   a. Side view or depth of shape - .25 inch

   b. Top view or width - .50 inch

   c. Front view or length - .50 inch

5. The shape selected for a control should not hamper control manipulation by personnel.

6. The shape surface in contact with the hand should have smooth edges and corners.

Size

1. Size coding should be used when only two or three controls are to be coded.

2. Size and shape coding may be used in combination, since the ability to discriminate shape is independent of size discrimination.

3. Controls performing the same function on different items of equipment should be coded consistently.

4. When size coding knobs with diameters between 0.5 inches and 4.0 inches, each successive knob should be at least 20% larger than the next smaller one.

Location

1. Coding of controls by location is most effective where blind-positioning movements are required.

2. For more accurate location discriminations, controls should be located forward of the operator.

3. Controls should be located in areas lower than the level of the operator's shoulders.

4. When locating controls in the forward area, a separation of 6 to 8 inches should be used for optimum discrimination.

5. When controls are located to the side or toward the back of the operator, a separation of 12 to 16 inches is recommended for effective operation and accurate discriminations.

Displays

Color

1. Color coding of transilluminated indicators should be used to indicate the type of action or response required as well as to indicate the status of equipment.

Color Banding of Display Scale Zones

1. Color codes, markings, and bands (see Fig. 49) should be used to optimize display reading performance in several ways:

   a. To make it obvious at a glance whether the indication falls within acceptable limits.

   b. To make it equally obvious when the indication falls within a "danger" range requiring immediate corrective action.

   c. To preclude the possibility of misreading numbers on the display or of mistaking a desired numerical value.

2. Since the appearance of colors often change under different types of illumination, it is important that color coded displays be used under white illumination only.

Shape

1. Shape coding of displays may prove useful in some instance but is not generally recommended.

2. Displays may be shape coded by scale zones (see Fig. 49). The shapes selected for coding purposes should be:

   a. Easily learned.

   b. Distinguishable under low illumination.

   c. Distinguishable under any color of illumination.

Size

1. Transilluminated indicator lights used to indicate emergency, failure, and master summation should be larger than general status indicators.

2. All other types of displays may be selected in varying sizes for purposes of coding.

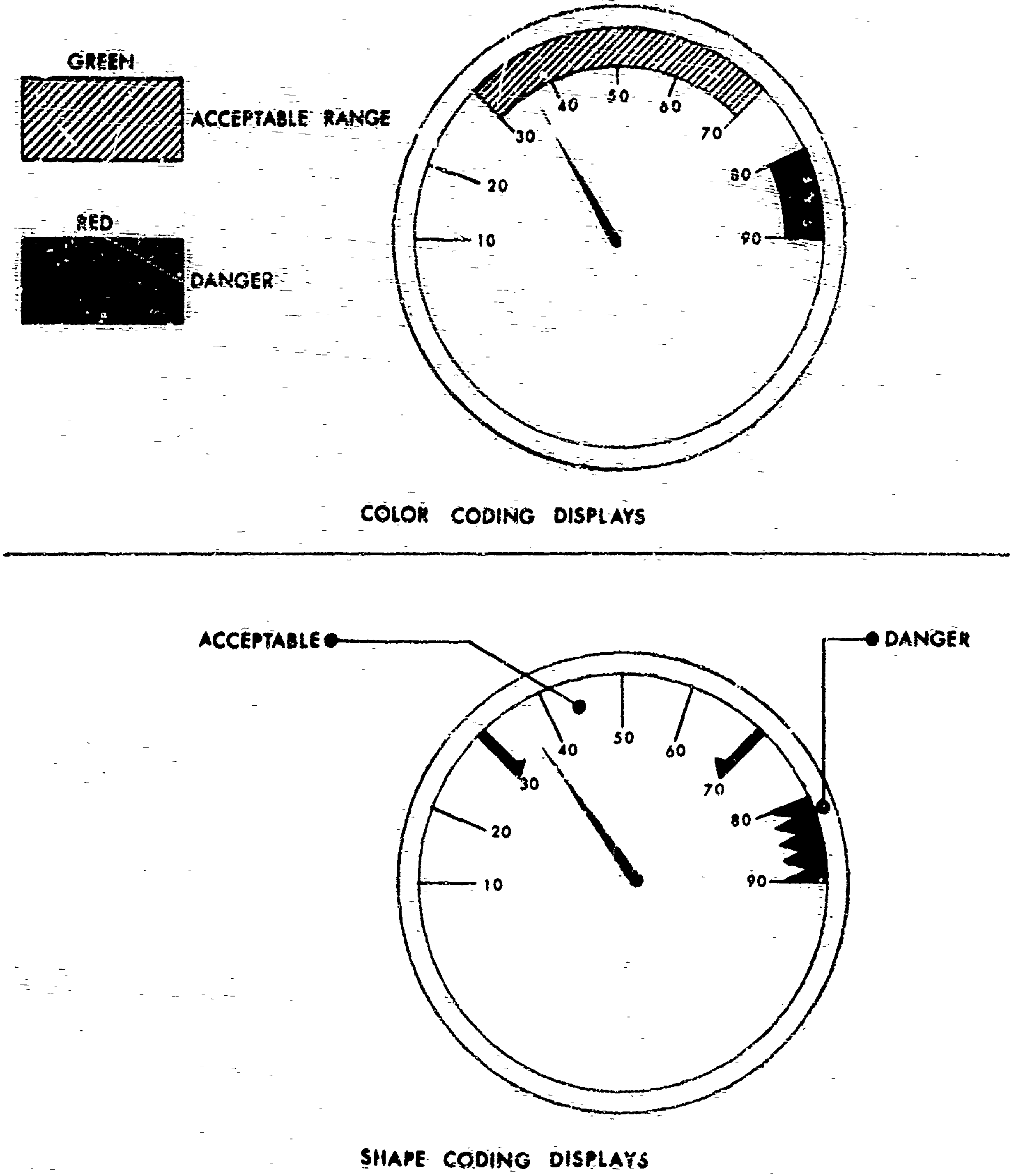


Fig. 49. Coding of Displays

Location

1. Location coding provides for the spacing or positioning of displays in groups so that they are distinguishable from each other.

2. Location coding may be achieved by:

   a. Adequate spacing of display groups; horizontal separations are preferable to vertical separations.

   b. Outlines around each unique display group.

   c. Placement on different planes with respect to the operator.

   d. Symmetry.

Connectors

1. All connectors should be coded to their mates. The coding of connecting devices such as receptacles and plugs is an important aid in making proper associations between input and output lines connecting different items of equipment.

2. The following general rules should be followed in color coding connectors:

   a. If possible, parts should be protected to prevent wearing, fading, and disappearance of color.

   b. Permanent methods are preferred rather than adhesive or bent-on tapes.

   c. If the number of items to be coded is too great to be accommodated by the available colors, matching patterns of colors or striping may be used.

3. Two color coding methods may be used for electrical connectors:

   a. The face of the receptacle and the base of the plug may be coded the same color.

   b. An area immediately adjacent to the receptacle may be coded the same color as a band on the plug.

4. Colors assigned for identification of connectors should be consistent in meaning with those used elsewhere in the system.

5. Connectors may also be coded by matching plugs and receptacles of various shapes (see Fig. 50). For example, the shape of the alignment pins may differentiate connectors and prevent mismatching of plugs and receptacles.

6. The requirement to match plugs with their proper receptacles may be met by size coding. In many instances, receptacles appearing in proximity to each other will already be of different sizes due to other requirements. However, when this situation does not apply and size coding is deemed necessary, receptacle sizes may be changed to aid in discrimination.

Conductors

Electrical Conductors

1. Where numerals are used to code conductors, the numerals should be placed at least 2 inches apart throughout the length of the conductor.

2. Color is the primary method of coding electrical conductors. The individual wires of all cabling should be color coded over their entire lengths. There are 21 different patterns of solid colors and solids with striped tracers that are discriminable (see Table 23). If more than 21 conductors are to be coded, the designer is referred to MIL-STD-686. Means of applying this coding system to conductors are, in order of preference:

   a. Solid colored insulator.

   b. Solid colored insulator with colored-stripe tracer.

   c. Colored braid with woven tracer.

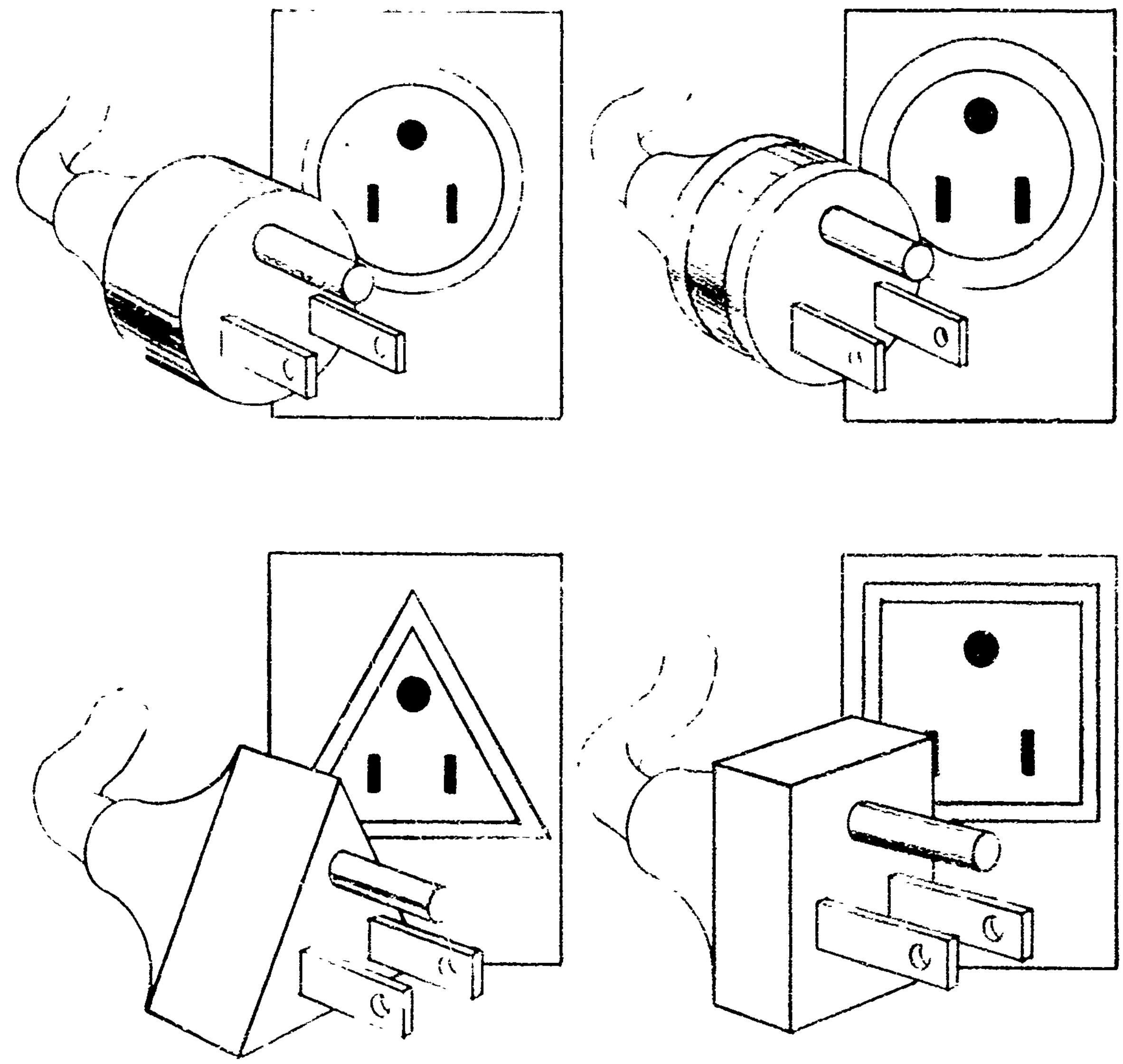


Fig. 50. Coding of Connectors

TABLE 23

CABLE CODING

Instructions:	Number of Conductors Desired	Basic Color	Tracer
1. Select the particular number	1	Black	None
of conductors desired to be	2	White	None
color coded.	3	Red	None
	4	Green	None
2. The colors appearing to the	5	Orange	None
right of the entry are the	6	Blue	None
appropriate combination for	7	White	Black
the particular number of	8	Red	Black
conductors.	9	Green	Black
	10	Orange	Black
3. For example, if a cable	11	Blue	Black
consists of 12 conductors,	12	Black	White
the twelfth color combination	13	Red	White
would be black and white.	14	Green	White
The eighth color combination	15	Blue	White
would be red and black. The fifth	16	Black	Red
color combination would be orange	17	White	Red
and so on.	18	Orange	Red
	19	Blue	Red
	20	Red	Green
	21	Orange	Green

Note: If a cable has concentrically laid conductors, the first combination or color applies to the center conductor. If a cable contains various sizes of conductors, the first color applies to the largest and the sequence continues in order of conductor size.

COMMUNICATIONS

General

1. Voice communication is the most common method of requesting and providing information. In military systems, communication may be transmitted two ways:

   a. Electrically, using radio or telephone.

   b. Operator to operator.

2. Electrically transmitted speech depends, to a great extent, on the characteristics of the microphone, transmission equipment, and the earphones; however, both direct and electrically transmitted voice communications have certain limitations in common. One of the limitations is the acoustical environment of both the speaker and listeners, and this factor is of great importance in determining communication effectiveness.

3. The frequency range from about 200 to 6000 cps contains most of the energy required for perfect speech intelligibility. However, this range may be narrowed to 300 to 4500 cps with little loss in intelligibility.

4. Most of the information carried in English speech is contained in consonants. Unfortunately consonants, which are in the high frequencies and contain little energy, are more readily masked than vowels.

5. Vowels produce more energy but transmit a very limited amount of intelligence. For example, the <u>s</u> sound is a high-frequency sound whereas the vowel <u>o</u> is a low-frequency sound.

6. Where the frequency band limits must be narrowed, the emphasis should be to retain the center of the frequency band near 1000 cps.

7. In order to obtain adequate intelligibility, it is not necessary that the communication system reproduce the entire audio spectrum. Satisfactory communications may be obtained by:

   a. Frequency response of $\pm$ 3 dB over the range of 300 cps to 4500 cps.

   b. A gain control with dynamic range sufficient to make the signal 15 dB more intense than the background noise but not to exceed 105 dB voice level at the ear.

8. Communication equipment should be located to insure the maximum audibility in the area served. When two or more items of audible equipment, i.e., telephone, radio, intercom, etc., present in a space, each should have a distinct tone.

9. In those cases where voice messages arrive at one central point from several sources then:

a. Where loudspeakers are used, the loudspeakers should be separated by more than 10 degrees in the horizontal plane, measured from the listener for ease of identification of the source.

b. Where a "trunk line" is used, the designer should insure that no two channels of communication overlap so as to cause message interference or distortion.

c. Indicator lights should be used to show the channel calling when identification is a major problem.

d. Facilities for switching to a loudspeaker from ear phones or the reverse should be provided for optional use by the operator.

10. At low ambient noise levels, telephone and announcing systems are equally useful. However, as the noise level increases, the usefulness of speakers drops off more rapidly than does that of telephones.

Telephone

1. A telephone should be used when:

a. Ambient noise and SIL are too high for an announcing system.

b. Messages are from one person to one person.

2. The following telephone equipment should be used:

a. A handset if the operator is in a fixed position and his hands are free.

b. A headset if the operator's hands must be occupied.

c. A headset and long extension cord if the operator must be mobile within a limited area.

Announcing System or Intercom

1. An announcing system or intercom should be used:

   a. In low-level ambient noise.

   b. When it is desirable to transmit to several stations simultaneously.

   c. When it is desirable for several persons within a space to receive simultaneously.

   d. When a person moving about within a space must receive.

Receiver and Headset

1. The receiver and headset should have the following characteristics:

   a. Gain control with dynamic range sufficient to make the signal 15 dB more intense than the noise but not to exceed 105 dB at the ear.

   b. Frequency response of $\pm$ 3 dB between 300 and 4500 cps to avoid distortion.

Talkers

1. Supervisory personnel may at times be required to maintain communications on or monitor more than one circuit at the same time. Such personnel should be provided with a talker to monitor and repeat messages on the major or the more important circuit.

2. The duties of the talker are to pass on outgoi messages and to report incoming ones to his principal.

3. A talker should be provided for a supervisor or equipment operator who:

   a. Is likely to receive a number of messages arriving on different channels.

   b. Is likely to receive so many telephone messages on a single channel as to distract him from his task.

c. Must move about in a space to the extent that an extension between him and a fixed jackbox or switchbox is impractical.

Radio Set

1. The radio set should be located in an area that offers maximum protection from system operational damage or inadvertent crew damage.

2. The location of the set should not interfere with the normal range of movement of the crew or be a hazard to the crew.

3. The control panel of the radio set should be visible and readily accessible to the radio operator.

4. The operator should be able to reach the radio control panel to change frequency without dismantling any portion of the system.

5. Where protective devices are provided within the equipment for primary and other circuits for protection of the equipment from damage due to conditions such as overload and excessive heating; provision should be made for visual checks of these devices.

6. Maintenance personnel should be provided with the capability of discharging capacitors before working on the high voltage circuits.

7. Each component with exposed terminals in medium- or high-voltage portions of a circuit should be protected from short circuit, grounding, or accidental contact by operating or maintenace personnel.

8. All external metal parts should be at ground potential.

Radio Antenna

1. The location of radio antennas should minimize the possibility of RF hazards to personnel.

2. On mobile missile systems having fully rotating launchers, the antenna should be located so that it will not be within the field of fire of the missile.

3. Antennas and wave-guides should be at ground potential except with regard to the energy to be radiated.

Control Box

1. All radio control boxes should be located for ease of access to all controls.

2. The location of control boxes should not interfere with the normal movements of personnel or present a hazard to them.

3. The control boxes should not be located where they could be used as a step or footrest.

4. It is important to locate the control boxes in a position which routes the headset and microphone cables clear of any rotating or moving linkages.

5. Control box location is limited by the effective operating length of the standard audio accessories used with radio-interphone equipments. The maximum distance that a control box should be installed from a crewman's normal working area is 30 inches.

6. Signal or warning lights which are part of the control unit should be located in such a manner that the signal warning is within the responsible crewman's field of vision.

Audio Accessories

1. Stowage hooks should be placed in the general area of each crew member for storing audio accessories when not in use.

2. Hooks should be located where they will be out of the normal path of movement of crew members.

Cable Routing

1. Interconnecting communication cables should be routed to minimize the possibility of their use as hand holds or steps. A protective guard should be placed over the cables where the possibility of this occurrence cannot be minimized.

2. All interconnecting cables should be routed in a neat manner eliminating droop and unnecessary loops in the cable. Cable clamps should be spaced approximately 12 [illegible]s apart.

OPTICAL INSTRUMENTS

General

1. Blinking of the eyes is an automatic process and will occur when using optical instruments because the eyes cannot focus steadily for very long without relaxing. It is muscular rather than retinal and is least apparent when the eye is relaxed and accommodated for distant objects.

2. Fatigue of the eye muscles will be experienced after comparatively short periods of continuous observation. Fatigue is usually greater under low illumination levels.

3. A particular type of fatigue results from the use of binocular instruments that cannot be set at the proper interpupillary distance. This is due to both eyes involuntarily adjusting themselves so that a single image is formed when the image is focused on the macula of each eye.

4. The more light of an evenly diffused nature that can be brought from the object to the eye, the brighter and clearer will be the image that is formed. This characteristic is known as image brightness. There is always a considerable loss of light by absorption in the lenses and by reflection at the surfaces of the optical elements. While this loss may be as great as 75 percent, every effort should be made to reduce the loss to a minimum.

5. A contributing factor in image brightness is an objective lens aperture large enough to permit the eye lens to produce an emergent beam that will fill the pupil of the eye. During the day the pupil of the eye is from 1/10 to 2/10 inch in diameter. At night the pupil may dilate until the diameter is from 1/4 to 3/10 inch. An instrument for use at night should have an exit pupil aperture of this size.

6. The true field of view of any optical instrument is the width and height of what can be seen at one time by looking through the instrument.

7. The maximum area of the field which might be imaged by the eyepiece is termed the apparent field of view. An apparent field of view of 45 degrees may be considered as a practical maximum for a highly corrected eyepiece. Thirty-five or forty degrees is a more common value.

8. The full apparent field of view of an instrument can only be seen when the pupil of the eye of the observer is at the same position as the exit pupil. The

distance from the eye lens to the exit pupil is termed the eye distance relief. The eye must be placed at this distance from a collective eyepiece in order to see most effectively through the instrument.

9. When the instrument imparts recoil to the observer, the eye distance becomes very important. In the design of the eyepiece, the proper location of the exit pupil must be given careful consideration. Therefore, proper eye relief should be consistent with the recoil characteristics of the weapon.

Interpupillary Distance

1. In designing instruments for use by both eyes, provision must be made for the adjustment of the spacing between the eyepieces of the instrument to conform to the interpupillary distance of different observers.

2. The interpupillary distance of such instruments should be adjustable from 57 to 72 millimeters. Where this is not done or provided in the design of the instrument, then:

   a. The line of sight of both eyes will not traverse the most effective optical paths of the instrument.

   b. The observer will not have full binocular vision nor view the most distinct images.

   c. The observer will not be able to seal out unwanted light from the eyepieces.

Focusing

1. The eyepiece of instruments having a magnifying power of more than 4X should be adjustable to accommodate the refracting qualities of the eyes of the individual observer. If the proper spectacles are worn by personnel, the corrected eye will focus at the normal setting of the instrument. However, the use of spectacles may prevent the eye from properly addressing the eyeshield of the instrument, thereby permitting stray light to enter the eyes. In addition, the eye may be placed so far from the eyepiece as to restrict the field of view.

2. Focusing eyepieces should have a graduated scale calibrated in diopters; the range of adjustment should be at least plus 4 to minus 4 diopters.

3. A single focus setting on instruments which have a magnifying power of 4X or less will have a sufficiently wide range of accommodation.

Filters

1. Light filters should be provided where necessary.

   a. Smoked (neutral) filters reduce the intensity of light and are effective when observing against or in the close vicinity of the sun or a bright light.

   b. Yellow and amber filters are used to protect the eyes from the reflection of sunlight on water and other general conditions of glare.

   c. Amber and red filters are employed under various conditions of fog and ground haze. Red filters are also used in observing tracer fire.

   d. Blue filters are helpful in detecting the outlines of camouflaged objects.

   e. Greenish-yellow filters are intended to serve the purpose of both smoked and amber filters.

   f. Polarizing filters do not change the color of objects but do decrease light intensity and glare.

Sight Elevation

1. The practice of making elevation correction for range by the operator's displacing the target image within the sight field imposes severe demands upon optical properties such as:

   a. Curvature of field generally present in optical systems and most marked in the lens erecting types (straight tube) introduces parallax which, if eliminated at the center, increases beyond the center of the field.

b. Curvature of the field also presents focal difficulties. Thus, if the eyepiece is set to give a zero diopter setting in the center (as for infinity) a positive diopter condition develops away from the center for which the normal eye cannot accommodate. This makes the image of distant objects appear blurred just where vision should be the clearest.

Boresight Knob Locks

1. Boresight knobs should be provided with a positive lock.

2. The application and release of the boresight adjustment knob locks should not require more than 10 pounds resistance to lock and unlock.

3. Boresight adjustment knobs should be capable of being unlocked, adjusted and locked by the 5th to the 95th percentile soldier's hand.

Slip Scales

1. Where slip scales are used these will be capable of being slipped by the hand of the 5th to the 95th percentile soldier.

2. The operation of slip scales should be by hand with no requirement for tools. Screwdrivers and wrenches are not acceptable.

Sight Mounts

1. The use of two or more dowel pins for final positioning of mounts on support surfaces provided on the weapon should be avoided.

2. Key and keyway, eccentric and keyway, and single dowel applications should be used for the final positioning of mounts.

3. Leveling vial supports should be strong enough to prevent the displacement of the bubble under slight pressure.

Eyepieces and Eyecups

1. Eyepieces or eyecups are fitted to fire control instruments to maintain proper eye distance and to protect the eyes of the observer from stray light, wind and injury due to the shock of gun fire or similar disturbances.

2. Eyepieces should be made of soft rubber or equivalent cushioning material.

3. The use and proper fit of the eyeshields should exclude stray light from the eyes. A proper fit of the eyeshields is particularly important in night observation or under conditions of poor illumination in order to dilate the pupil as much as possible.

4. The eyepiece should be compatible with the helmet, gas mask or other ancillary equipment.

Brow Pad

1. The object of a cushioning device such as a headrest or brow pad is to absorb energy which would otherwise be absorbed by the human head, with resulting damage to its internal organs, bone structure or external tissues.

2. The cushion has the function not only of spreading the force over a greater time but also over a greater surface area, thus preventing a damaging amount of force from being exerted at any one point.

3. There are three general types of cushion material, as shown by the load-deflection curves in Fig. 51. These curves are idealized and do not represent existing materials.

4. The curves have been drawn so that each one represents a cushion which has the normal characteristics required to provide the desired protection. For example, each curve reaches an assumed maximum tolerable force of 160 pounds at a compression of 0.9 inch. The 160 pounds is roughly the product of an assumed weight of 12 pounds for the head plus helmet and an assumed 13 g's maximum tolerable acceleration of the human head. The 0.9 inch maximum allowable compression assumes an eye relief distance of 1.25 inch and a safety clearance of 0.35 inch. In each case the curve rises steeply after 0.9 inch in order to provide enough stopping force to prevent further travel, which might result in collision of the eye with the eyepiece of the telescope. However, in spite of the similarities, the three cushions depicted are not at all equal in effectiveness.

5. The energy in inch pounds absorbed by the cushion is given by the area under the load-deflection curve. It can be seen from Fig. 51 that the most energy absorption is provided by the cushion for which the force rises rapidly and then reaches a plateau for the rest of the compression distance. The higher energy absorption capacity means that a greater velocity of the pad-supporting structure relative to the head can be tolerated.

6. So far, the shock has been considered as if it were a single event, resulting in only one compression cycle of the pad. Actually, the firing of the weapon results in a series of oscillations of the vehicle structure, against which the head must be protected to a greater or lesser degree, depending on amplitudes and frequencies of the oscillations.

7. The optimum protection of the head requires that the head-plus-headrest system have a natural resonance frequency differing as much as possible from the frequencies occurring in the weapon structure, and also different from the natural frequencies of the head itself.

8. A large damping coefficient is desirable only if the exciting frequency is less than three times that of any existing natural resonance frequency, otherwise the presence of damping actually increases the amount of force transmitted through the cushion by decreasing the mechanical impedance.

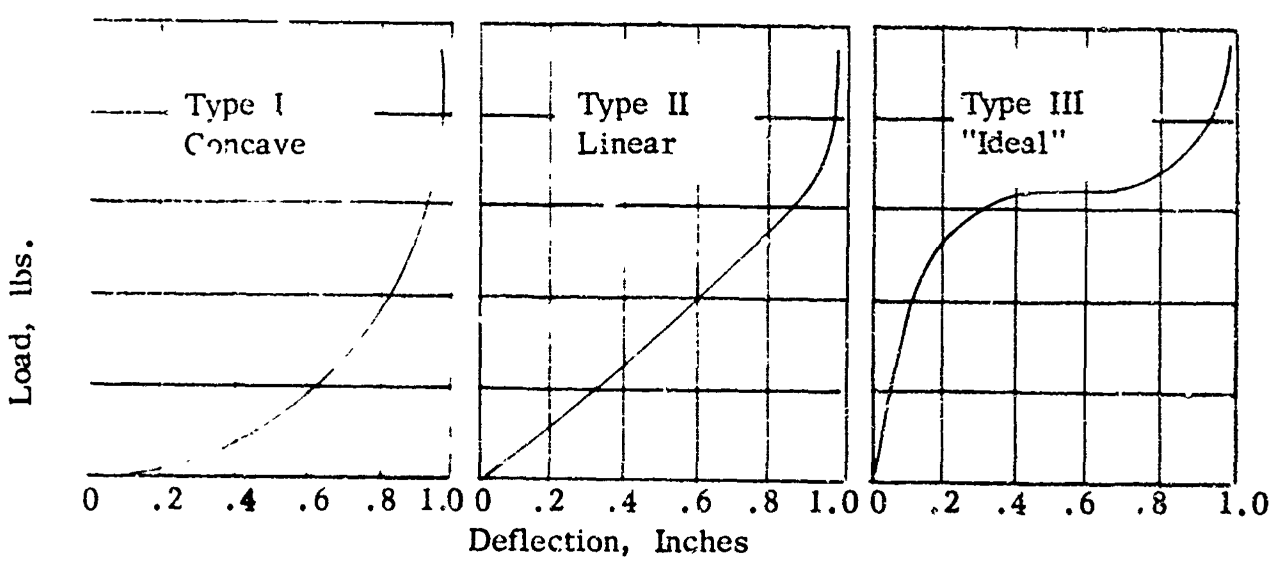


Fig. 51. Types of Cushion Material

Sights for Night Operation

1. Where continuous use of a sight will exceed one minute, the single optical train sight should be equipped with two eye pieces.

2. Where an illuminated sight is used, it should be possible to gradually lower the brightness of the reticle until it is extinguished.

   a. Once an adjustment is made, the level of brightness should remain fixed under all conditions of vibration.

   b. The sight reticle should be evenly illuminated by means of an opal diffuser or some similar device.

3. Blue is unsuitable for reticle color because of the difficulty in accommodating.

4. A black reticle line decreases the visibility not only of targets covered or partly covered by the line, but also for those lying near the line. This characteristic is particularly true for indistinct, camouflaged, or small targets, or for hazy conditions. These effects may have some influence as far as 2 1/3 mils from the edge of each line.

5. Within limits aiming is not affected appreciably by considerable variation in reticle thickness; thin lines give personnel a feeling of precision when they are aiming. The lines should be .5 minute or more in thickness.

6. The following factors should be considered in the design of reticles:

   a. Line reticles are superior to reticles containing one, two or three central spots.

   b. The use of two vertical spots for any length of time fatigues the aimer and produces inaccurate results.

   c. A single spot is not as effective as a ring.

   d. A small cross or very small circle is better than a dot.

   e. The best pattern for a night sight is a simple circle with tabs added to the sides.

7. A complicated reticle pattern may cause aiming errors as large as 30 mils through interference with a distinct view of the target.

STOWAGE

General

1. Stowed items should be secured by straps, brackets or other restraining devices to allow cross-country operation without endangering personnel or displacing the stored item.

2. Items which are inflammable or subjected to damage by leakage of lubricants, fuels or water should be stowed to receive reasonable protection from engines, generators, exhaust components, etc.

3. All stowage locations should drain adequately with the vehicle on level ground. Drain holes should be arranged so that they will not be blocked by normal stowage.

4. Climatic factors should be considered in the location of items that must be worn by crew members.

5. Climatic factors should be considered in the location of items which would be prevented from being operated by personnel as a result of exposure to the environment.

6. All stowed equipment should be capable of being safeguarded from pilferage.

7. Floor stowage boxes should not interfere with crew footing.

8. Items of mission-critical nature should be stowed within easy reach of crew members.

9. The location for stowed items should be clearly and permanently labeled with the identity of the item.

Interference

1. Stowed items should not interfere with the entrance, exit, escape, movement or operations of personnel.

2. Stowage should not interfere with system functions.

3. Stowed items should be capable of being removed and replaced without the removal or replacement of other stowed items or components of the system.

4. Items to be stowed sho · e capable of being stowed and unstowed by the 5th through 95th percentile m .n, wearing gloves, without havir to assume an unnatural position.

Utilization of Stowage Space

1. The stowage of equipment should follow the functional utilization of each item in the determinati ... y and location.

2. Items to be utilized b ... his task requirement should be stowed in a c ... ation within the functional area of his st

3. Dead space should be utilized to the maximum extent possible to stow items.

4. Stowage should be available for such items as individual weapons, small arms ammunition, rations and the M-1 helmet and liner if special headgear is required while equipment is operating.

Retaining Devices

1. Retaining devices should be simple and capable of quick removal and replacement.

2. Items should be capable of being stowed and unstowed by hand; no tools should be required.

3. Items should be capable of being stowed and unstowed under all conditions of environment.

Missile Stowage

1. Stowage racks should be designed so the missiles can be placed in and removed from stowage easily.

2. The missiles should be protected from falling out of stowage or from contacting each other in stowage.

3. The stowage rack should be designed and located to minimize interference with the working area.

4. Personnel should be capable of removing and replacing missiles from the stowage rack without striking any protrusions.

5. Missile rack latching mechanisms should be of quick-release design and require no more than 12 pounds to operate.

6. It should be readily obvious to personnel when the missile rack latching mechanisms are in the locked position but not secured.

7. Vertically stowed missiles weighing over 40 pounds should have a floor retainer which has sufficient clearance to allow missile placement and removal by the 95th percentile hand (see Fig. 52).

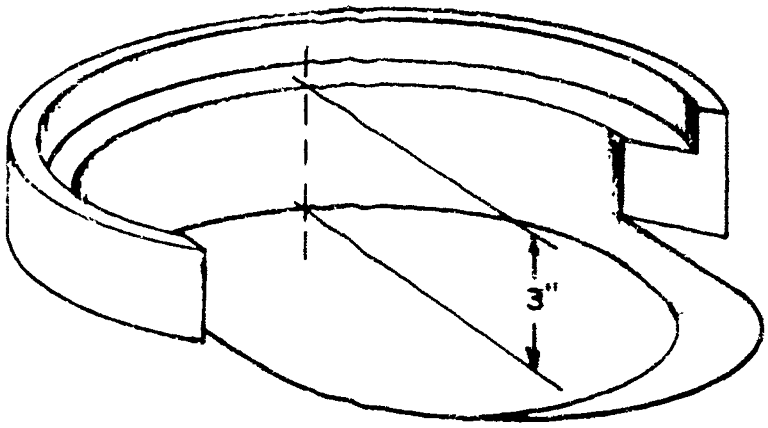
Missile Transfer

1. Where a hoist is used, the missile should be prevented from swinging about, thereby endangering personnel or damaging equipment.

2. The hoist clamp should be designed to prevent accidental release of missiles.

3. Provision should be made for manual operation of the hoist in case of power failure.

4. Unobstructed work space should be provided for transferring the missiles from stowage to the launcher.



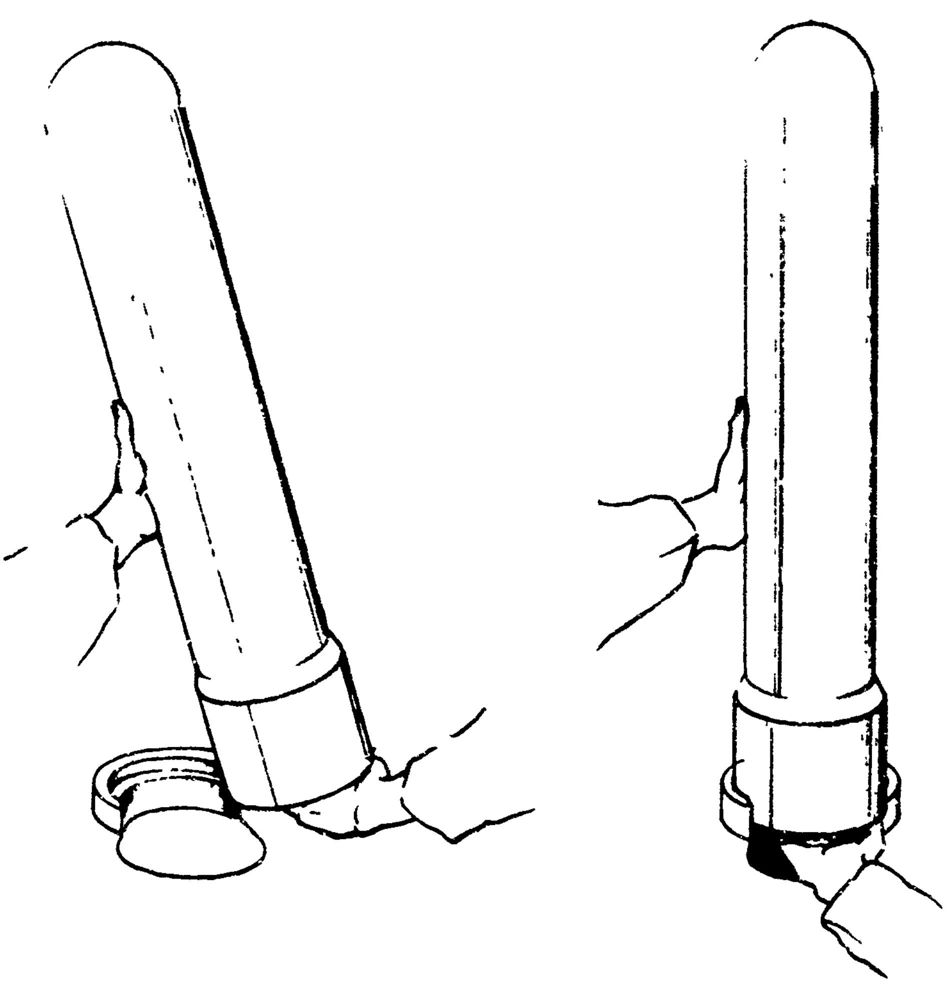


Fig. 52. Retainers for Floor Mounted Vertical Missile Racks

MAINTENANCE

General

1. The Army program for materiel readiness emphasizes the complementary attributes of reliability and maintainability. Reliability is best expressed as the probability the materiel will perform its intended function, i.e., remain in a state of readiness, without maintenance or with only planned maintenance. Maintainability is the degree of facility with which the materiel is capable of being retained in, or restored to, a state of readiness and availability. It is a function of parts accessibility, internal configuration, use and repair environment, and the time, tools and training skills required to effect maintenance.

2. The objectives of improved maintainability are:

   a. To increase the availability of materiel for the performance of its function and mission.

   b. To reduce costs of operational support within the planned service life of the materiel.

3. Designers of materiel for the Army should contact the Maintenance Directorate of the Commodity Command responsible for procurement for guidance and latest data available pertaining to the Army Maintenance Program when designing for maintainability.

4. Maintainability must be designed into the materiel in the earliest stage of development if costly maintenance or costly redesign is to be avoided, it is therefore imperative that a design schedule for maintainability be programmed to include the following steps:

   a. Planning for Maintainability

   b. Designing for Maintainability

   c. Testing and Revising the Design

5. In planning for Maintainability the designer should:

   a. Study an operational vehicle or materiel resembling the one to be designed. List the maintenance features built into it and from a study of maintenance history and experience, list the maintenance features that should have been built into it, but, were not.

b. Determine the measurements of access opening sizes, work surfaces and access space the maintenance personnel will have to go through to get to the components.

c. Find out what tools and test equipment are currently in the system that might be adapted for use on the materiel being designed.

d. Determine what type, the number and organization of manuals the maintenance personnel will need to maintain the materiel properly, effectively, and safely.

6. In designing for Maintainability the designer should consider:

a. Modular or unit packaging, and where feasible, throw-away units.

b. Replaceable modules or units that are independent and interchangeable. The replacement of a unit should not require extensive adjustment or realignment of other units.

c. Ease of access to perform checks or to service the materiel.

d. An equipment design that can be serviced where it is finally installed.

e. Design of equipment so that standard test equipment already in the system can be used. Where standard test equipment cannot be used, design and build special test equipment and plan to have it ready for issue when the materiel is ready for issue.

7. The development and production models should be tested for maintainability under operational conditions using representative Army personnel. These tests should demonstrate the following:

a. Use of the procedures, tools, test equipment and manuals that will be available to the maintenance personnel.

b. Use of maintenance personnel that are no more highly trained than those likely to be assigned the maintenance mission in the field.

8. Maintenance manuals should be ready for issue at the same time the materiel is released for use.

Tools

1. Equipment design that can be repaired and serviced with standard tools and as few tools as possible; where special tools are required, they should be designed and ready for issue with the materiel.

General Work Space Requirements

1. The system work space requirements should be based on the following minimum considerations:

   a. The interrelationships of personnel and equipment in the work area.

   b. Points where operation and maintenance are or may be required.

   c. Space and clearance needed to accommodate personnel in anticipated body positions, utilizing test equipment where needed, to perform the functions of operation and maintenance.

   d. Requirements for access or passage to the work point. The size and weight of equipment carried and used at the work station.

   e. Requirements for wrenching space, grasping space, etc., about the items to be manipulated.

2. The work space should allow personnel to change their body position if the task requires kneeling, crawling, or crouching for a prolonged period of time. Considerations must also be given for providing protection against any potential hazards which might exist while personnel are performing their tasks.

3. The following representative features should be provided at the work station, where appropriate, to assist personnel in the performance of their jobs.

   a. Auxiliary hooks, holders, lights, outlets, etc.

   b. Non-skid treads, expanded metal flooring, or abrasive coating on all surfaces which may be used for walking, climbing, or footholds.

4. Top surfaces of equipment should be reinforced (use 250 pounds per man to calculate anticipated load) and provided with non-skid surfaces whenever they may be used as work platforms.

General Access Requirements

1. Where possible and feasible, the design for accessibility should be approached on a grand scale by:

   a. Using modular design.

   b. Using hinged or removable chassis.

   c. Designing major units and assemblies, particularly engines, turbines, etc., with removable housings to make complete inspections possible.

   d. Hinging missile skin for ease of access to assemblies and accessories during major checkouts, turn-arounds, etc.

   e. Correlating the design of unit accessibility features with the accessibility requirements of the overall system.

2. Accesses should be designed, located, covered, and fastened in such a manner as to avoid the necessity for removing components, wires, etc., to reach the item requiring maintenance. These openings should be in a direct line with equipment to be serviced or maintained.

3. The design should be such that the removal of any replaceable item requires opening of only one access, unless the accesses are of the latched and hinged door type.

4. Items requiring visual inspection (hydraulic reservoirs, gauges, etc.) should be located so that they can be observed without the removal of panels or other components.

5. The edges of accesses should be lined with internal fillets or other suitable protection wherever sharp edges might otherwise injure technicians, hoses, etc.

6. Visual access should be provided for all maintenance operations requiring visual control and, particularly, where hazards can be encountered within the access. The technician should not be required to work blindly.

7. Where accesses are located over unavoidable dangerous mechanical or electrical components, the access door should be designed so that when opened, it turns on an internal light and provides a high visibility warning label on the door.

8. Safety interlocks should be provided on access leading to equipment with high voltages. If the equipment circuit must be "on" during maintenance, a cheater switch should be provided that automatically resets when the access is closed.

Access

1. Access must be provided to all points, items, units, and components which require testing, servicing, adjusting, removal, replacement or repair.

2. The type, size, shape and location of access (see Table 24 and Figure 53 through 55) should be based upon a thorough understanding of the:

   a. Operational location, setting and environment of the unit.

   b. Frequency with which the access must be entered.

   c. Maintenance functions to be performed through the access.

   d. Time requirements for the performance of these functions.

   e. Types of tools and accessories required by these functions.

   f. Work clearances required for performance of these functions.

   g. Type of clothing likely to be worn by the technician.

   h. Distance to which the technician must reach within the access.

   i. Visual requirements of the technician in performing the task.

   j. Packaging of items and elements, etc., behind the access.

   k. Mounting of items, units and elements, behind the access.

   l. Hazards involved in or related to use of the access.

   m. Size, shape, weight and clearance requirements of logical combinations of human appendages, tools, units, etc., that must enter the access.

TABLE 24

ONE-HAND ACCESS OPENINGS

(A) Arm to elbow:

Light clothing:	4.0" x 4.5" or 4.5" dia.
Arctic clothing:	7.0" sq. or dia.
With object:	Clearances as above.

(B) Arm to shoulder:

Light clothing:	5.0" sq. or dia.
Arctic clothing:	8.5" sq. or dia.
With object:	Clearances as above.

MINIMAL FINGER ACCESS TO FIRST JOINT:

(C) Push button access:	Bare hand:	1.25" dia.
	Gloved hand:	1.5" dia.
(D) Two finger twist access:	Bare hand:	2.0" dia.
	Gloved hand:	2.5" dia.
(E) Vacuum tube insert:	Miniature tube:	2.0" dia.
	Large tube:	4.0" dia.

3. For ease of maintenance, the following types of access are listed in order of preference (see Fig. 56):

a. Uncovered or exposed equipment - When structural, environmental, operational, and safety conditions permit, equipment should be left exposed for maintenance. This is particularly true of test and service points, maintenance displays and controls, and rack-mounted "black boxes."

b. Semi-exposed equipment - Semi-exposure can be accomplished by means of:

(1) Pull-out racks or drawers.

(2) Full-length doors on cabinets or equipment racks.

(3) Quick-opening hoods or covers.

(4) Easily and quickly removable dust covers and cases.

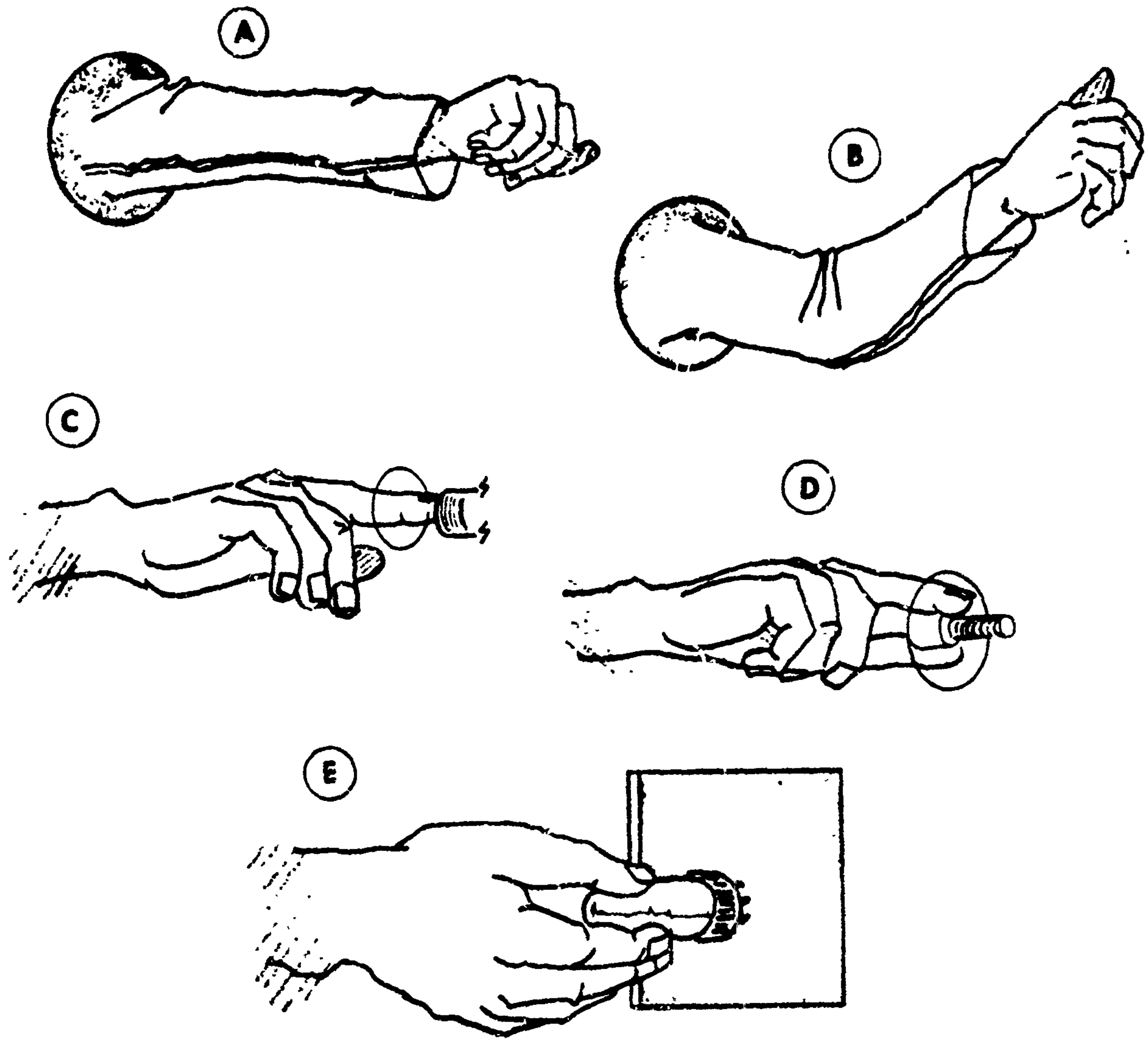


Fig. 53. One Hand Access Openings

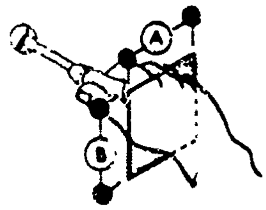
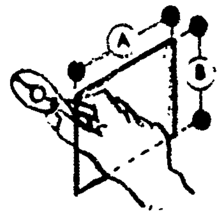
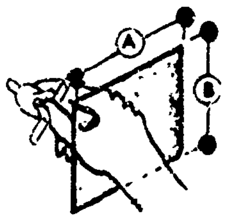
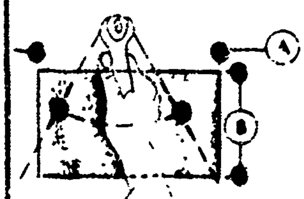
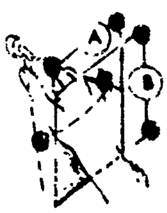
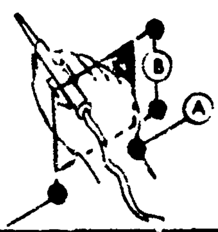
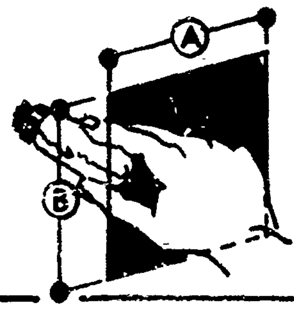
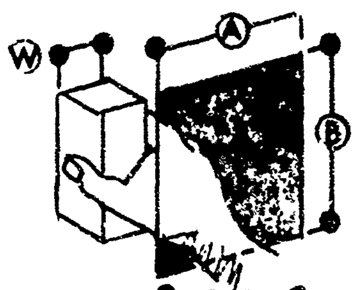
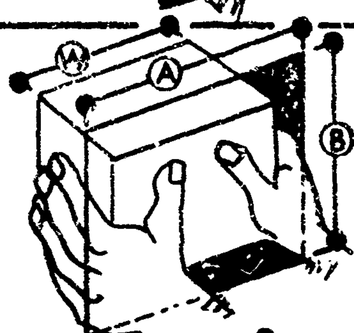
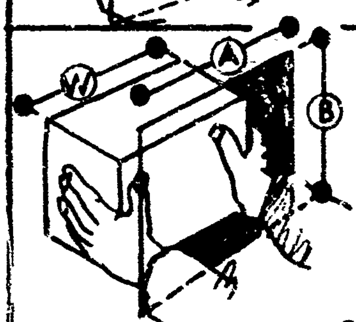
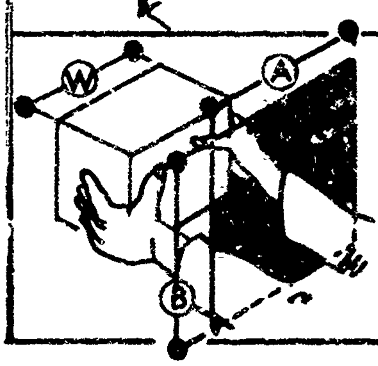
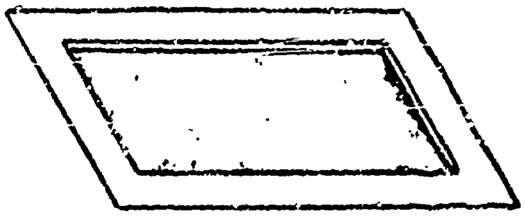
OPENING DIMENSIONS	DIMENSIONS (In Inches) A	B	TASK
	4.2	4.6	Using common screwdriver, with freedom to turn hand through 180°.
	5.2	4.5	Using pliers and similar tools.
	5.3	6.1	Using "T" handle wrench, with freedom to turn hand through 180°.
	10.6	8.0	Using open-end wrench, with freedom to turn wrench through 60°.
	4.8	6.1	Using "Allen"-type wrench, with freedom to turn wrench through 60°.
	3.5	3.5	Using test probe, etc.

Fig. 54. Access Opening Dimensions

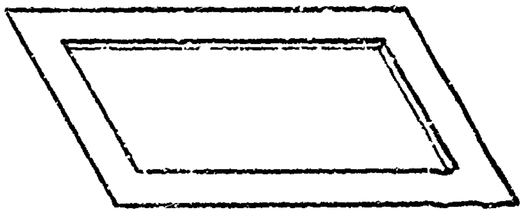
OPENING DIMENSIONS	DIMENSIONS (In Inches) A	B	TASK
	4.2	4.7	Grasping small objects (up to 2-1/16" diameter).
	W+ 1.75	5.0**	Grasping large objects with one hand (2-1/16" wide).
	W+3.0	5.0**	Grasping large objects with two hands, with hands extended through openings up to fingers.
	W+6.0	5.0**	Grasping large objects with two hands, with arms extended through openings up to wrists.
	W+6.0	5.0**	Grasping large objects with two hands, with arms extended through openings up to elbows.

**Or sufficient to clear part if part is larger than 5.0".

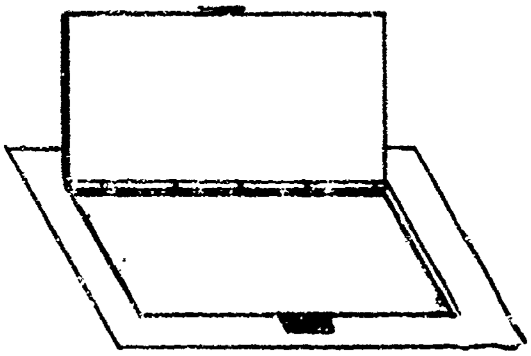
Fig. 55. Access Opening Dimensions



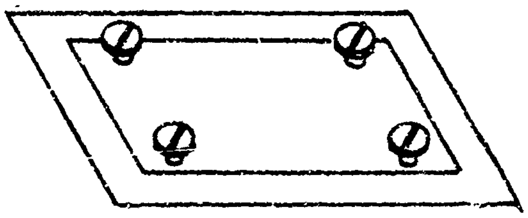
BEST - NO COVER
(Use Whenever Possible)



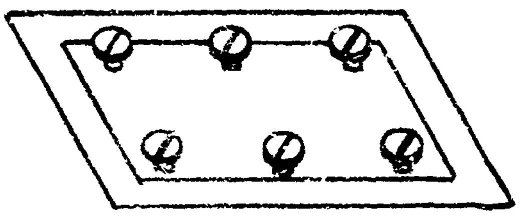
PERMANENT GLASS OR PLASTIC COVER
(Use Where Visual Inspection Only is Required)



SLIDING OR HINGED COVER
(Use Where Physical Access is Required and Where Dirt and Moisture Could be a Problem)



CAPTIVE QUICK-OPENING FASTENERS
(Use When Space Prevents Use of Hinged Cover)



SCREWED-DOWN COVER
(Use Only When Stress or Pressurization Requires. Keep Number of Screws Down to a Minimum)

Fig. 56. Covers and Accesses

c. Uncovered, limited access openings - Uncovered openings should be used only when environmental control is not required and when danger to equipment or personnel is minimal. Work clearances around mounts, components, etc., should be considered as uncovered, limited access openings.

d. Covered, limited access openings - Covered accesses should be evaluated in terms of the types of covers and fasteners employed.

e. Stress doors - Stress doors are usually required in high performance equipment, but should be avoided wherever possible. When required, the accessibility of stress doors can be improved by selection of appropriate fasteners.

f. Riveted panels and doors - Riveted panels are never acceptable as access points. Overall layout and design of equipment should not require removal of permanently attached structures even for infrequent maintenance.

4. The size of the access should be dictated by the same considerations as shape.

5. In general, one large access is preferable to two or more small ones; but where structural or other considerations are required, visual and physical access may be provided separately.

6. Where stress doors are employed, or access covers are otherwise difficult to remove, a smaller access to frequently used test or service points should be provided.

Shape of Accesses

1. Accesses should be whatever shape is necessary to permit easy passage of the required items, body appendages, implements, etc. The following should be considered:

a. Dimensions of the various items that must be replaced through the access.

b. Protuberances, attachments, handles, etc., on these items.

c. Methods of grasping items during removal, and the required clearances.

d. Requirements for work clearance for work within the compartment.

e. Requirements for visual control of functions performed within the compartment.

2. Accesses need not be of regular geometric shapes; the designer should consider irregular shapes that will best satisfy both structural and accessibility requirements.

Location of Accesses

1. Accesses should be located:

    a. Only on equipment faces that will be accessible in normal installation.

    b. For direct access and maximum convenience for job procedures.

    c. On the same face of the equipment as the related displays, controls, test points, cables, etc.

    d. Away from high voltages or dangerous moving parts, or provide adequate insulation, shielding, etc., around such parts to prevent injury to personnel.

    e. So that heavy items can be pulled out rather than lifted out.

    f. In keeping with the Work Space Requirements on page 183.

    g. So that the bottom edge of a limited access is no lower than 24 inches or the top edge no higher than 60 inches from the floor or work platform.

    h. So that they conform to heights of work stands and carts related to use of the access.

Connectors

1. Connectors should be compatible with:

    a. Lines and Cables (Page 217).

    b. Fastener requirements (Page 208).

    c. Mounting and packaging requirements (Page 222).

d. The environmental extremes to which they will be subjected.

e. The maintenance routines in which the connectors will be involved.

2. Connectors should be selected, designed and mounted to:

a. Maximize the rapidity and ease of maintenance operations.

b. Facilitate the removal and replacement of components and units.

c. Minimize "set-up time" of test and service equipment.

d. Minimize dangers to personnel and equipments from pressures, contents or voltages of lines during the release of connectors.

e. Be operated by hand where possible, or with common hand tools.

3. Connectors should be standardized to minimize the likelihood of mismating, cross connection, or similar errors during installation or maintenance.

4. Standardization should provide clearly different and physically non-interchangeable connectors for lines that differ in content--i.e., different voltages, oils, gases, etc.

5. Connectors should be located and mounted so they are accessible:

a. With a minimum of disassembly or removal of other equipments or items.

b. In proportion to the frequency with which they must be operated; those used during pre-operating checks should be most accessible.

6. Connectors should be located so that:

a. They can be easily reached for connection or disconnection.

b. Easy visual access is provided to allow starting of connector threads or pins without potential damage to the connector.

c. Spillage or leakage of fluids is minimized and, where it occurs, will not damage equipment.

d. Connectors are far enough apart or from other obstructions so they can be grasped firmly for connecting and disconnecting.

7. In general, minimum separation between connectors should be as follows:

a. 0.75" if only the bare fingers are required.

b. 1.25" if bare hand or gloved fingers are to be used.

c. 3.00" if a gloved or mittened hand must be used.

d. As required for tool clearances.

8. Connectors should be designed and located to minimize dangers to personnel and equipment from pressures, contents, or voltages of lines during release or handling of connectors.

9. The design and location should prevent damage to connectors, connector parts, and contacts from:

a. Movements of personnel, shifting objects, opening doors, etc.

b. Excessive tightening or man-handling during operation.

c. Shorts, or arcing as a result of foreign objects, erroneous connection, or handling after disconnection.

10. Protection of connectors should be provided by:

a. Recessing receptacles as necessary.

b. Recessing delicate connector parts (pins, keys, etc.) within the connector so they are not subject to harmful contact.

c. Providing protective caps, inserts, covers, cases, and shields as necessary.

11. Connectors should be selected, designed, and installed to provide positive means of preventing mismating or cross connection. The following means should be considered:

a. Provide different size or different type connectors or similar, adjacent leads.

b. Arrange lines so that the distances from the connector to the correct point of attachment prevents mismating.

c. Arrange lines or provide separation blocks or other mounts so the sequence of leads is obvious.

d. Polarize or use different sizes of prongs and prong receptacles. This will prevent mismating between lines of differing voltage values.

e. Use differen and mutually incompatible and irreversible arrangements of guide pins, keys or prongs.

f. Adequate color coding or labeling of connectors and their receptacles so confusion is minimized and mismating is unlikely.

12. Connectors and associated parts and wiring should be coded and identified as necessary to:

a. Facilitate reference to them in the job instructions.

b. Identify replaceable items and parts to allow reordering.

c. Expedite and facilitate maintenance procedures and trouble-shooting procedures.

d. Reflect the sequentiality of routine procedures and test procedures.

e. Provide continuity of reference throughout the system.

f. Provide adequate warnings or cautions relevant to connector operations.

13. Labels or codes should be provided on connectors and receptacles, as necessary, to ensure that:

a. Each plug is clearly identified with its receptacle.

b. Each wire is clearly identified with its terminal post or pin.

c. Test points are clearly identified by a unique mark or symbol.

d. Non-interchangeable connectors are clearly distinguishable.

e. The manner of connection or disconnection is clear.

f. Plugs and receptacles have painted strips, arrows, or other indication to show orientation of aligning pins for proper insertion.

g. Terminal strips and circuit boards are marked in a permanent manner so as to identify individual terminals and facilitate connector replacement.

h. Power receptacles for primary, secondary or utility systems are clearly labeled to prevent personnel injury or equipment damage.

14. Labels or codes on connectors and associated items should be located so that:

a. They are maximally visible under operational maintenance conditions.

b. They are visible in both connected and disconnected conditions. Connectors can be identified without having to be disconnected.

c. Labels are in a consistent position relative to their associated pins, terminals, receptacles, etc.

d. Where room is unavailable for complete labels, simple symbols are provided and are explained on a nearby plate or in the job instructions.

15. The order of preference for placement of labels or codes is:

a. First - Directly on the connector and receptacle.

b. Second - On plates permanently affixed to the connector and receptacle.

c. Third - On tabs or tapes attached to the connector.

d. Third - In the case of receptacles, on the immediately adjacent surface, panel or chassis.

e. Third - In the case of receptacles, on or near the access opening, if recessed.

Classification of Connectors (by preference of use):

1. Plug-in connectors are the fastest and easiest to use but they have low holding power; therefore:

a. They should not be used where holding power is such that lines are likely to be damaged or connectors loosened by the pulling required to disconnect.

b. Where possible, they should be used for all connections that will not be seriously stressed and particularly for those that must be frequently disconnected.

2. Quick-disconnect devices exist in a variety of forms and include any type of connector that can be released by snap action, twisting up to a full turn, triggering a latch or spring device, or removing an external pin.

3. Quick-disconnect devices should be used for connections of:

a. Items which require frequent disconnection or replacement.

b. Items which require replacement within critical readiness times.

4. Threaded connectors provide very secure connection, particularly when locked into place by set screws, retainers or safety wires. Usually they require more time to operate, depending on the number of turns required and the types of tools required.

5. Threaded connectors should:

a. Require the minimum number of turns consistent with holding requirements.

b. Be operable by hand when used for electrical connection.

c. Require only common hand tools.

d. Be designed and arranged to reduce the danger of accidental loosening of other connectors while working on one.

Electrical Connectors

1. Insertion forces of electrical connectors should be kept low to minimize the possibility of damaging contact surfaces on connector parts.

2. Electrical plugs should be designed, installed and mounted so that:

a. It is impossible to insert the wrong plug into a receptacle.

b. It is impossible to insert a plug the wrong way in its own receptacle.

c. Multi-contact plugs are used wherever possible, to reduce the number of plugs and the number of maintenance operations required.

d. Plugs "plug-in" or require no more than one complete turn to effect secure connection, especially for connection of auxiliary or test equipment.

e. Wiring is routed through the plugs and receptacles so disconnection does not expose "hot" leads.

f. All "hot" contacts are socket contacts, e.g., receptacles are "hot" and plugs are "cold" when disconnected.

g. Plugs are self-locking, or use safety catches rather than require safety wiring.

3. Alignment keys or pins should be designed and located with the plug so that:

a. They extend beyond electrical pins to protect the pins from damage due to misalignment.

b. They are arranged asymmetrically to prevent incorrect plug insertions.

c. All alignment pins for a given plug or series of plugs are oriented in the same direction. If this conflicts with mismating requirements orientation of the pins should differ in a consistent and systematic manner, in order to be maximally convenient to the technician.

4. Test points should be:

a. In plugs when such testing is required and other special test points have not been provided.

b. In adaptors to be inserted between the plug and receptacle, if it is not feasible to provide test points in the plug and other adequate test points are unavailable.

c. Accessible in terms of clearances and relationship to the normal setting of the plug or adaptor.

d. Coded and labeled to be clearly visible and identifiable in test procedures.

Fluid and Gas Connectors

1. Connectors for pipes, tubing, hoses, etc., should be located and installed so that:

   a. Draining, filling, or other maintenance involving the connectors can be accomplished without jacking up the equipment.

   b. Leakage tests can be performed easily and without endangering the technician. Tests should be planned so the technician does not have to insert his head into areas of extreme noise, vibration or other danger while the equipment is running.

2. Gaskets and seals used in the connection of fluid or gas lines should be selected and installed to:

   a. Be easily replaceable without removal of other connector parts or disassembly of other equipment.

   b. Be identifiable with part numbers so they can be easily ordered and handled logistically. The job instructions should state the expected life of seals and gaskets and recommend when they should be changed.

3. Gaskets and seals should be used that are visible externally after they are installed, to reduce the common failure to replace seals during assembly or repair.

Covers and Cases

1. Covers, cases and shields should be provided as necessary to:

   a. Divide enclosures into sections which differ by types of cleaning methods to be used.

   b. Protect personnel from coming in contact with dangerous electrical or mechanical parts.

   c. Protect delicate or sensitive equipment from damage by movements of personnel, shifting of cargo or loose objects, or actions involved in the installation and maintenance of nearby assemblies.

2. In addition to the criteria implicit above, covers, cases, and shields should be designed and evaluated in terms of the degree to which they contribute or detract from the speed and ease with which required maintenance can be performed, (see Fig. 57). Their value in this respect largely depends upon:

a. The manner in which they are fastened.

b. Their size, weight, and ease of handling.

c. Provisions for handles or tool grips.

d. The work space and clearance around them.

e. The frequency with which they must be opened or removed, in terms of the reliability and maintenance requirements of the enclosed components.

3. The cover, case or shield should:

a. Be lightweight, if possible, but be whatever size is necessary to accomplish the degree of enclosure and allow the degree of accessibility required.

b. Be openable, removable and transportable by one hand, one man, or, at most, two men, in that order of preference.

c. Be provided with lifting eyes and planned for crane handling if more than 150 pounds.

d. Be provided with handles or tool grips if heavy or difficult to open or handle.

e. Allow sufficient clearance around enclosed components to minimize damage to these components and to avoid requirements for extremely fine or careful positioning and handling.

f. Be designed and located so that bulkheads, brackets, or other units will not interfere with operation of the cover or case and so the cover or case, when opened, will not interfere with other maintenance operations.

4. The shape of the cover, case or shield should:

a. Be whatever shape is necessary to accomplish the degree of enclosure, allow the degree of accessibility, and provide the clearances required.

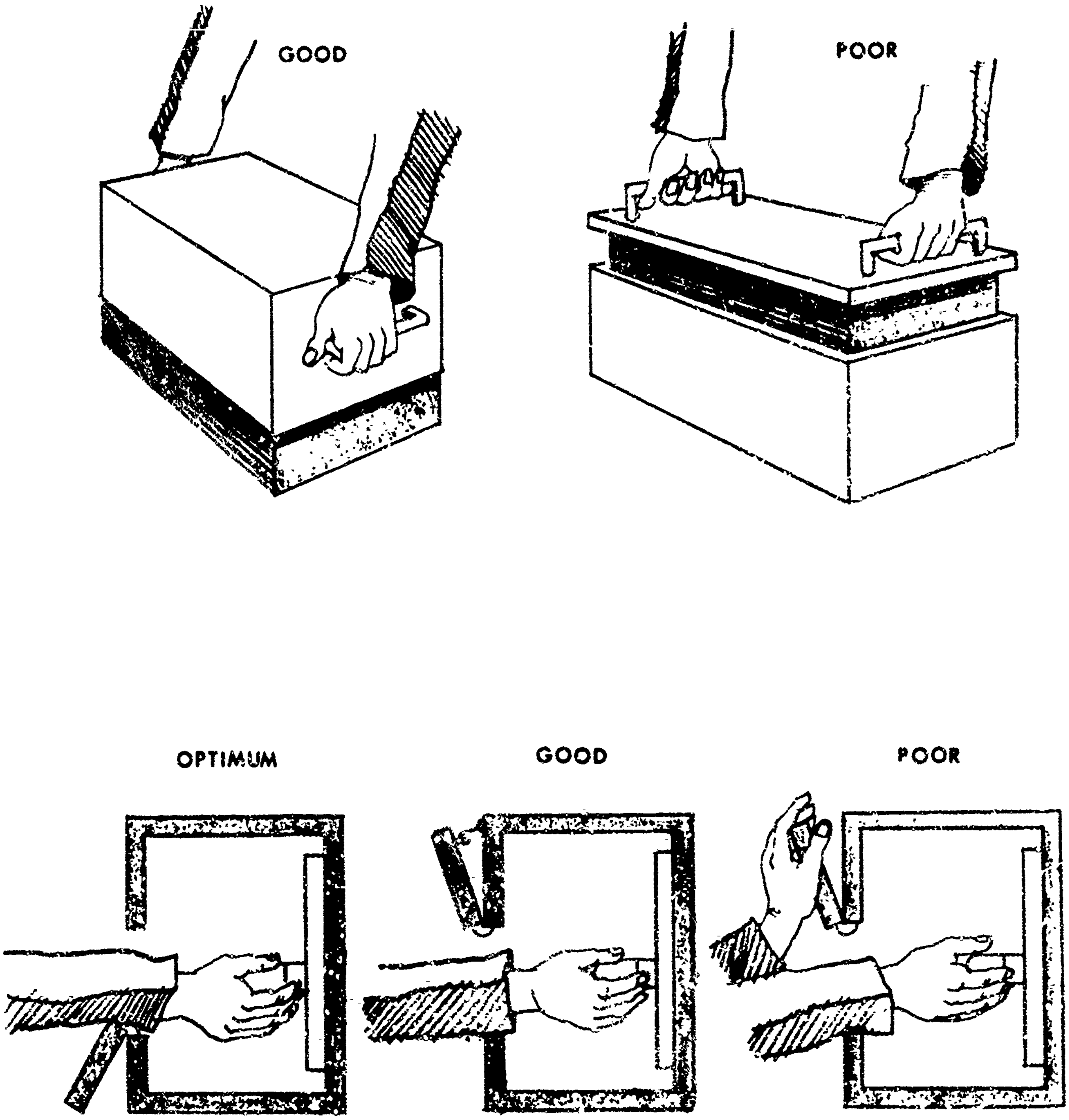


Fig. 57. Covers and Case Design Examples

b. Make obvious the manner in which the item must be positioned or mounted.

c. Make obvious the orientation of enclosed delicate components, to minimize damage to these during removal of the items.

d. Be free of indentations or settling areas on top surfaces to reduce rust, corrosion, and the accumulation of dirt and grease.

5. Covers, cases and shields should be designed, located and mounted so that:

a. They are completely removable and replaceable in case of damage.

b. Irregular extensions and accessories can be readily removed.

c. They can be opened or removed as necessary when the equipment system is completely assembled and auxiliary equipment has been installed.

d. They do not cause the equipment to become unbalanced when opened by providing props, retainers, or other support where required.

e. They do not obscure or interfere with controls, displays, test points, or connections related to work within the access or enclosure, when in the open position.

f. They are provided with adequate stops and retainers to prevent them from swinging into or being dropped on fragile equipment or personnel.

g. They are provided with locking devices or retainer bars to lock them in the open position if they might otherwise fall shut and cause damage, injury or inconvenience. This is particularly necessary for doors, covers and shields which may be used in high winds.

6. Fasteners for covers, cases and shields should be selected, applied and mounted so that:

a. They optimally satisfy the preferences, requirements and standardization aspects under "Fasteners" (page 206).

b. Maximum use is made of hinges and latches or catches to minimize the requirements for handling and stowing covers and cases.

c. It is obvious when a cover or case is not in place or securely fastened. Where possible spring load fasteners so they stand out or the cover itself stays ajar when not secure.

7. Labels and markings on covers and cases should:

a. Provide opening, removal or positioning instructions, if methods for accomplishing these are not obvious from the design.

b. Adequately reveal the functions of units behind the enclosure or the functions which are to be performed through the access, such as "Battery," "Fuel Pump," "Oil Here," etc.

c. Adequately warn against dangers or hazards involved in removing the cover or case or working within the enclosure.

d. Provide the proper orientation or connection of units, service equipments, etc., to go through the opening, if this is not clear or visible.

e. Provide instructions which will be visible and oriented with respect to maintenance technician when the cover, door or case is open.

8. Cases should be selected, designed, and mounted so that:

a. They are lifted off units, rather than items lifted out of cases, particularly when heavy subassemblies are involved (Fig. 57).

b. They are sufficiently larger than the items they cover to expedite removal and replacement and prevent damage to wires or other components during removal or replacement.

c. Guidepins and tracks are provided as necessary to help align the case, prevent it from cocking or binding, and to prevent damage to delicate or sensitive components during movement of the case.

d. Access is provided to frequently used adjustment, test, or service points, so that the case need not be removed in routine maintenance.

e. All maintenance-significant aspects and portions of the equipment are fully exposed when the case is removed.

f. Rubber stripping or other sealing material is selected and mounted so it will not be damaged by personnel when the case is moved.

9. Covers should have the following characteristics; these are listed in order of preference:

a. Hinged doors, hoods, and caps allow the fastest and easiest access, reduce the number of fasteners required, and support the cover so the technician does not have to handle it. Such covers do, however, require "swinging space" and may interfere with other operations or components. When hinged covers are used, the following should be considered:

(1) Where opening space is a problem, double-hinged or split doors should be used.

(2) Hinges should be placed on the bottom, or a prop, catch or latch should be provided so the door will stay open without being held. This is particularly necessary if the door must be opened in high winds (see Fig. 57).

(3) Adjacent hinged doors should open in opposite directions to maximize accessibility; and cabinets should be so arranged that functionally related cabinets are adjacent and open in opposite directions.

(4) Hinged caps over service or test points should be designed so as not to interfere with the insertion or attachment of service or test equipment.

(5) Stops, retainers, etc., should be provided as necessary to prevent the door from swinging into adjacent displays, controls or fragile components, and to prevent springing of the hinges.

b. Sliding doors or caps are particularly useful where "swinging space" is limited. Small sliding caps are useful for small accesses that do not require a close seal. When sliding covers are used, the following should be considered:

(1) Sliding doors and caps should lock positively.

(2) They should be designed to avoid jamming or sticking.

(3) They should be easy to use and should not require tools for operation.

(4) Their movement should not interfere with, damage or provide potentially harmful contact with wires or other equipment items.

c. Removable doors, plates or caps require little space for opening and, once removed, do not interfere with work space. However, their handling requires time and effort, e.g., searching, bending, reaching, etc. When removable covers are used, the following should be considered:

(1) Maximum use should be made of tongue-and-slot, or similar catches for small plates, doors and caps to minimize the number of fasteners required.

(2) Small plates and caps that are likely to be misplaced or damaged should be secured with retainer chains in accordance with the section on "Fasteners," (see page 206).

(3) If a removable plate must be attached in a certain way, design so that improper attachment is impossible, e.g., use an asymmetric plate shape, locate mounting holes asymmetrically, or code both plate and structure so the coded labels are aligned when the plate is properly installed.

d. Removable panels or sections are useful where access to whole sides of a cabinet or equipment is required. They discourage non-maintenance personnel from opening the access. They do not require "swinging space," but are easily damaged, and are awkward to handle. They may also interfere with maintenance activities. When used, the following should be considered:

(1) Panels, intended to be removed for ease of maintenance, should be held with a minimum number of combination-head, captive fasteners. Spring-loaded, quarter-turn fasteners are particularly recommended.

(2) Such fasteners should give position indication when they are released--e.g., release should be clear prior to movement of the panel.

(3) Panels and sections should be removable with common hand tools, portable and installable by one man.

(4) Panels and sections should be provided with handles to facilitate removal, handling, and replacement.

(5) It should not be necessary to disconnect wires, components, etc., from a panel before it can be removed. Where such items are attached to the panel, the panel should be hinged to make removal of these items unnecessary.

c. Stress covers and doors on high performance equipment usually require a great many fasteners to meet operational requirements. The speed and ease with which such doors and covers can be opened and used can be greatly increased by the use of captive, quick-release fasteners which satisfy the system requirements.

Fasteners

1. The design, selection or application of fasteners should take the following factors into consideration:

a. Work space, tool clearance and wrenching space should be provided around the fastener.

b. The types of tools required for operation of the fastener, as a function of fastener type, application and location.

c. The frequency with which the fasteners will be operated.

d. The time requirements of tasks involving operation of the fasteners.

2. Fasteners are available in a wide variety of types and sizes within each category, and new types are always appearing. The application of fasteners should be preceded by a review of the varieties available. Fasteners should be selected and evaluated on the basis of durability, ease of operation, speed, ease of replacement and other criteria of this section.

3. To the maximum extent possible, fasteners should be standardized to reduce storage of spare parts and to minimize the danger of damage by use of the wrong tool or fastener for a given application.

4. The design should minimize the number of types and sizes of fasteners within the system by:

a. Using only a few basic types and sizes which can be readily distinguished from each other (see Fig. 58 for representative examples).

b. Using the same type and size of fastener for a given application, e.g., all mounting bolts the same for a given type of item.

c. Making certain that screws, bolts, and nuts of different thread size are of clearly different physical sizes, otherwise they may be interchanged.

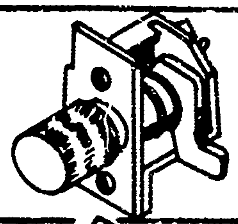
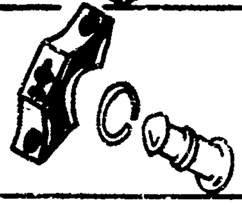
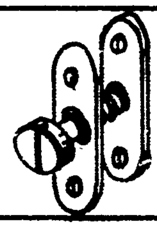
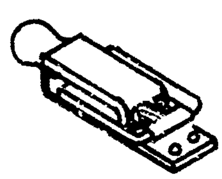
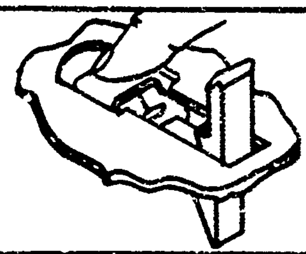
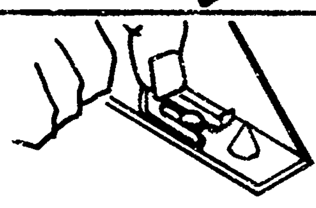
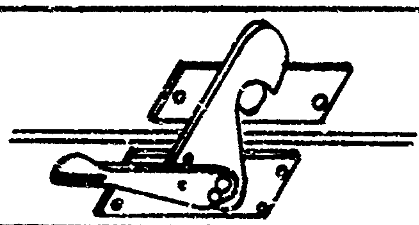
TYPE	DESCRIPTION
	Adjustable pawl fastener As knob is tightened the pawl moves along its shaft to pull back against the frame. 90° rotation locks, unlocks fastener.
	"Dzus"-type fastener with screwdriver slot Three-piece 1/4-turn fastener. Spring protects against vibration. 90° rotation locks, unlocks fastener.
	Wing head. "Dzus" type 90° rotation locks, unlocks fastener.
	Captive fastener with knurled, slotted head The threaded screw is made captive by a retaining washer.
	Draw hook latch Two-piece, spring latch, base unit and striker. Engagement loop is hooked over striker and lever is depressed, closing unit against force of springs. Lever is raised to unhook.
	Trigger action latch One-piece, bolt latch. Latch is opened by depressing a trigger to release bolt which swings 90° under spring action. To close move bolt back into position.
	Snapslide latch One-piece snapslide. Latch is opened by pulling lever back with finger to engage release lever.
	Hook latch Hook engages knob on striker plate. Handle is pulled up locking in place. To release reverse procedure.

Fig. 58. Fastener Examples

5. The design should minimize the number of tool types and sizes required for faster operation by:

   a. Avoiding requirements for special tools.

   b. Selecting fasteners for hand operation or operation by common hand tools.

6. The replacement of stripped, worn or damaged fasteners should be considered in design. Fasteners (studs) which are part of the housing should be avoided.

7. Fastener mounting holes or other tolerances should be large enough to allow "starting" of fasteners without perfect alignment.

8. Hinges, catches, latches, locks and other quick-disconnect devices should be attached by means of small bolts or screws, not rivets.

9. Nuts and bolts, particularly those which are frequently operated or poorly accessible, should be mounted so they can be operated with one hand or one tool by:

   a. Providing recesses to hold either the nut or bolt.

   b. Semi-permanently attaching either the nut or bolt.

   c. Using double nuts on terminal boards and similar applications.

   d. Using nut plates, gang-channeling or floating nuts.

10. A few large fasteners should be used rather than many small ones, except where system requirements dictate.

11. Fasteners should be located so that they:

   a. Can be operated without prior removal of other parts or units.

   b. Can be operated with minimum interference from other structures.

   c. Do not interfere with each other or other components during release.

   d. Do not constitute a hazard to personnel, wires or hoses.

   e. Are surrounded by adequate hand or tool clearance for easy operation. Requirements for two hands or power tools for manipulation, breakaway, or removal of stuck fasteners should be given consideration.

Types of Fasteners (listed in order of preference)

1. Quick connect-disconnect devices - These are fast and easy to use, require no tools, may be operated with hand, and are very good for securing plug-in components, small components and covers. However, their holding power is low and they cannot be used where a smooth surface is required.

2. The following factors should be considered in the selection of quick connect-disconnect fasteners:

   a. They should be used wherever possible for components that must be frequently dismantled or removed.

   b. These devices must fasten and release easily, without the use of tools.

   c. They should fasten or unfasten with a single motion of the hand.

   d. It should be obvious when they are not correctly engaged.

   e. When many are used and misconnection is possible, the female section should be located, shaped, sized or coded so that only the correct male section may be attached.

3. Latches and catches - These are very fast and easy to use, require no tools, have good holding power, and are especially good for large units, panels, covers and cases. They cannot be used where a smooth surface is required.

4. The following factors should be considered in the selection of latches and catches:

   a. Long latch catches should be provided so that inadvertent springing is minimized.

   b. Spring-load catches should be provided that do not require positive locking, but lock on contact.

   c. Where a handle is used in conjunction with the latch, the latch release should be located on or near the handle so that only one hand is needed for operation.

5. Captive fasteners - These are slower and more difficult to use, depending upon type, and usually require the use of common hand tools; but they stay in place, save the time spent handling and looking for bolts and screws, and require only one-handed operation.

6. The following factors should be considered in the selection of captive fasteners:

a. Captive fasteners should be used wherever "lost" screws, bolts or nuts might cause a malfunction or excessive maintenance time.

b. Fasteners should be used which may be operated by hand or common hand tool.

c. Fasteners should be used which may be easily replaced in case of damage.

d. Self-locking, spring-loaded action should be provided on captive fasteners of the quarter-turn type.

7. Regular screws - Round, square or flat-head screws require more time and are more subject to loss, slot damage, stripping and misapplication.

8. Square-head screws are generally preferable to round or flat since they provide better tool contact, are less subject to slot damage, and may be removed with pliers.

9. The following factors should be considered in the selection of screws:

a. Deep slots should be provided on screw heads to minimize slot damage.

b. Screws should be used only when screwdrivers may be used in a "straight-in" fashion; the use of offset screwdrivers should not be required.

10. When a screw must be operated blindly, a tool guide in the assembly should be provided.

11. Bolts and nuts - Bolts are usually slow and difficult to use; they require two-handed operation, access to both ends of the bolt, and often the use of two tools. They also require precise movements in starting nuts, and have many loose parts to handle and lose (nuts, washers, etc.).

12. Bolt length should not be more than required for a given purpose to avoid snagging personnel or equipment.

13. Left-hand threads should be used only when system requirements dictate; both bolts and nuts should be clearly identifiable by marking, shape or color.

14. Wing or knurled nuts, which require no tools, should be used for low-tension applications. Wing nuts are the easier to use.

15. Combination-head bolts and screws - These should be used in preference to other screws or bolts simply because they may be operated more rapidly with either a wrench or a screwdriver; this allows use of the more convenient tool, and reduces the possibility of slot damage and stuck fasteners. In general, slotted, hexagon heads are preferable to knurled and slotted heads.

16. Internal wrenching screws and bolts - These allow higher torque, better tool grip, and less wrenching space. But they are easily damaged, are difficult to remove when damaged, and require special tools.

17. The following factors should be considered in the selection of this type fastener:

a. The number of different sizes should be minimized to require only one, or as few as possible, special tools.

b. Slots should be deep, to minimize damage to the fasteners.

c. Design should allow and plan for the removal of damaged internal wrenching fasteners in terms of clearances, power outlets, etc.

18. Rivets - Permanent fasteners are very hard and slow to remove and replace. They should not be used on any part which may require removal.

19. Cotter key use should consider the following:

a. Keys and pins should fit snugly, but should not require driving in or out.

b. Heads of cotter keys should be large, to facilitate removal.

20. Safety wire use should consider the following:

a. Use safety wire only where self-locking fasteners or cotter pins are not adequate to withstand the expected vibration or stress.

b. Attach safety wire so it can be easily removed and replaced.

21. Retainer ring use should consider the following:

a. Use only rings which may be removed and replaced easily when worn.

b. Use rings which hold with a positive snap action when possible.

22. Retainer chains should be used to:

a Keep hatches or doors from opening too far and springing their hinges.

b. Turn doors or covers into useful shelves for the technician.

c. Prevent small covers, plates, or caps from being misplaced.

d. Secure small, special tools to the location in which they will be used.

e. Secure objects which might otherwise fall and cause personnel injury.

23. The selection of retainer chains for use in design should consider the following:

a. Link, sash, or woven-mesh type chains should be used. Bead-link chain is not recommended because it breaks more easily than other types.

b. Chains should be attached with screws or bolts; attachment should be strong and positive, but easily disconnect when required.

c. Eyelets should be provided at both ends of the chain for attaching to the fasteners.

d. Chains should be no longer than necessary to fulfill their function.

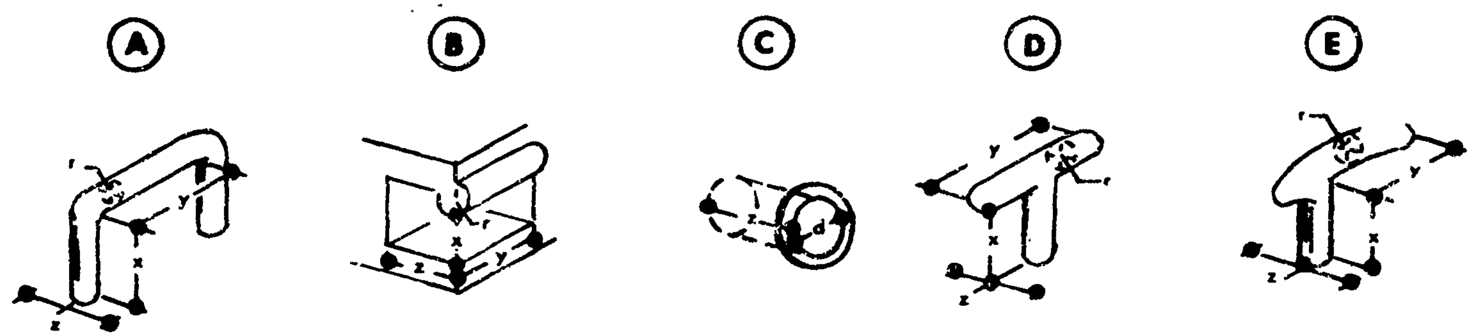
e. Chains to filler caps should be attached externally rather than internally to facilitate replacement and prevent broken parts from damaging equipment.

Handles

1. The dimension (Fig. 59), location and positioning of handles are functions of the:

a. Weight of the item or unit.

b. Number of men, or hands, required to lift or carry the item.



Type of Handle:	(Bare Hand) X	Y	Z	(Gloved Hand) X	Y	Z	(Mittened Hand) X	Y	Z
A. Two-Finger Bar	1.25"	2.5"	1.5"	1.5"	3.0"	1.5"	Not Applicable		
One-Hand Bar	2.0"	4.25"	2.0"	2.5"	4.75"	2.0"	3.0"	5.5"	3.0"
Two-Hand Bar	2.0"	8.5"	2.0"	2.5"	9.5"	2.0"	3.0"	11.0"	3.0"
B. Two-Finger Recess	1.25"-dia.		2.0"	1.5"-dia.		2.0"	Not Applicable		
One-Hand Recess	2.0"	4.25"	3.5"	2.5"	4.75"	4.0"	3.0"	5.5"	5.0"
C. Finger-Tip Recess	0.75"-dia.		0.5"	1.0"-dia.		0.75"	Not Applicable		
One-Finger Recess	1.25"-dia.		2.0"	1.5"-dia.		2.0"	Not Applicable		
D. T-Bar	1.5"	4.0"	1.5"	2.0"	4.5"	2.0"	Not Applicable		
E. J-Bar	2.0"	4.0"	2.0"	2.0"	4.5"	2.0"	3.0"	5.0"	3.0"

Curvature of Handle or Edge:

Weight of item	Radius of Curvature (minimum)
up to 15 lbs:	R - 1/8 in.
15 to 20 lbs:	R - 1/4 in.
20 to 40 lbs:	R - 3/8 in.
Over 40 lbs:	R - 1/2 in.

Gripping efficiency is best if finger can curl around handle or edge to any angle of 120 degrees or better.

Fig. 59. Minimum Handle Dimensions

c. Type of clothing and gloves worn by these men.

d. Operational position of the item relative to other items and obstructions.

e. Manner in which the item is to be handled or positioned.

f. Distance over which the item must be carried.

g. Frequency with which the item must be handled or carried.

h. Additional uses the handle could serve.

2. Handles should be designed and located to:

a. Guard against inadvertent actuation of controls.

b. Protect delicate parts of instrument faces.

c. Serve as locking devices to secure components in place.

d. Serve as protective supports or stands for components (e.g., can be used as maintenance stands when items are inverted).

3. Hand-shaped handles should be provided when items must be carried frequently or for long periods, to prevent undue side pressure on the fingers.

4. Recessed, concealed or folding handles may be used to conserve space, but they must be accessible without tools and must remain securely folded when not in use.

5. The location of handles should be such that:

a. Single handles are over the center of gravity.

b. Two or four handles are at equal intervals from the center of gravity.

c. Handles are placed where they do not interfere with equipment operation or maintenance.

d. At least a 2.5-inch clearance between handles and obstructions is provided.

e. They are placed on the front of a panel if an item must be pulled from the rack.

f. They can be held comfortably.

g. The carried item will ride clear of the legs of personnel.

6. Handles, lugs, and other handling gear (casters, push bars, etc.) should be permanent parts of the equipment case.

7. Hoist lugs (lifting eyes) should be provided on all equipment weighing more than 150 pounds. Mark "LIFT HERE" adjacent to each lug, and provide a minimum of 4 inches about the lifting eyes, for convenient use.

Handling Equipment

General

1. Handling equipment includes that ground support equipment used for the handling, lifting and positioning tasks required during missile system maintenance.

Jacks

1. Jacks should be designed so they can be transported, handled and stored easily. Small jacks that are to be lifted and carried by one man should not exceed 40 pounds.

2. Jack handles should be removable or designed to fold when not in use.

3. Jacks should be labeled to indicate:

a. The direction of jack handle rotation for raising or lowering.

b. The load they are designed to carry.

4. On hydraulic jacks, one or more access plates should be provided for inspection and cleaning of the hydraulic fluid reservoir.

5. On hydraulic jacks, mechanical safety-locking devices should be provided to prevent accidental lowering of the load if the hydraulic system fails.

Cranes

1. Crane boom sections should have hook eyes at the centers of gravity to facilitate boom assembly and disassembly.

2. Where feasible, the boom length should be adjustable to make the equipment more versatile.

3. The crane operator's station should be located to provide maximum visibility of the load, the ground and other equipment in the vicinity.

4. The main boom angle indicator display should be easily visible to the operator and coded to alert the operator when the maximum load angle is in danger of being exceeded.

5. A safety interlock device should be provided to cut crane hoist power when a maximum load is approached to prevent tipping the crane.

6. Boom controls should be labeled to indicate function and direction of motion.

7. Boom controls should be spring loaded to return to the stop position when released.

8. Handles should be provided on crane hooks to preclude injury to fingers when holding or guiding hooks during lifting operations.

9. Crane hooks should have safety closure locking devices over the mouth of the hook that can be readily opened or closed by personnel.

10. The retaining or locking device used to preclude movement of the boom during crane transportation should be clearly and unambiguously identified.

Hoists

1. Hoists should have an automatic cut off of power to stop lifting when a bind occurs.

2. Moving parts of hoists, i.e., belts, chains, gears, etc., should be covered to prevent personnel coming in contact with them.

3. The hoist control box should be light-weight and designed to be hand held.

4. The hoist control box should be small enough so the operator may reach the "up" and "down" control buttons while holding the box securely and comfortably.

5. Where a push button control is used, it should be spring loaded to the off position and recessed.

6. The "up" and "down" hoist controls should be clearly labeled, preferably on the control.

Lines and Cables

1. Lines and cables should be selected, designed, bound, routed, and installed to provide for and facilitate rapid:

    a. Troubleshooting, testing, checking and isolation of malfunctions.

    b. Tracking, removal, repair, and replacement.

    c. Removal and replacement of other items and components.

    d. Connection and disconnection.

2. Lines and cables should be compatible with:

    a. Connectors (Page 192).

    b. Fasteners (Page 206).

    c. Accesses (Page 185).

    d. The environmental extremes to which they will be subjected.

3. Lines and cables should be standardized, where possible, to minimize the number of:

    a. Types and varieties of lines and cables.

    b. Different lengths of lines and cables of the same type.

    c. Related connectors, fittings fixtures and features.

4. Lines and cables should be routed and mounted so they are accessible:

    a. With a minimum of disassembly or removal of other equipment or items.

    b. Particularly at points of connection, mounting, splicing or testing.

c. For complete removal and replacement in case of damage.

d. Accesses and clearances should be provided for such removal and replacement.

5. Lines and cables should be routed in a manner that precludes their use as a hand-hold or foot rest.

6. Lines and cables should be routed and mounted so that they are not snagged by moving or rotating parts and do not interfere with normal operation.

7. Clamps or mounting plates used to mount lines and cables should:

a. Be spaced not more than 24 inches apart for rapid removal.

b. Be lined with a low heat conducting material if the line is likely to become extremely hot. See Table 9, page 54.

c. Require only one-handed operation with or without common hand tools.

d. Be of a quick release, hinged or spring type if the line or cable must be frequently removed. Hinged clamps are preferred because they support the weight of the line during maintenance, freeing the technician's hands for other tasks. For overhead mounting, be of a spring clamp type with a hinged locking latch over the open side of the clamp to prevent accidents.

8. Adequate handling and storing provisions should be made for lines and cables of the extension type, or which are part of ground power, service and test equipment. The following should be considered:

a. Adequate, covered storage space should be provided in support equipment for storing lines and cables.

b. Suitable racks, hooks, or cable winders should be provided within the storage space to hold the lines and cables in a convenient and accessible manner.

c. Reels or reel carts should be provided for the handling of large, heavy, or very long lines and cables. Automatic or power tensioning or rewinding reels should be used, where possible, to maximize ease of handling.

d. Wheels or other mobile supports should be provided for extra large lines and cables that must be frequently moved.

Fluid and Gas Lines

1. During servicing or maintenance operations the possibility of mismating connectors may be avoided by:

   a. Standardizing fittings so that it is impossible to interchange lines that differ in content.

   b. Employing arrangement, size, shape, and color coding as necessary to prevent interchange of adjacent lines.

   c. Identifying all fluid carrying lines by color bands.

2. Spraying or draining on personnel or equipment during disconnections may be avoided by:

   a. Locating connections away from work areas and sensitive components.

   b. Providing shielding for sensitive components where required.

   c. Providing drains and bleed fittings to allow drainage or reduction of pressure prior to disconnection.

   d. Providing high visibility warning signs at disconnect areas or where pressures or the content of lines could injure personnel.

3. High pressure lines should have a retaining chain attached to the line and the source to restrain the line if the connector accidentally separates from the receptacles.

4. Drainage problems should be avoided by:

   a. Avoiding low points or dips in lines that are difficult to drain.

   b. Designing lines so they can be completely emptied when required.

   c. Making bends, where possible, in the horizontal rather than the vertical plane, to avoid fluid traps.

   d. Providing low point drains where required to drain such traps.

5 Mounting and installation should be such that:

   a. Installed rigid lines with fittings do not require the line to be backed-off for disconnection.

   b. Tubing is used in preference to rigid lines where applicable,

as it allows more flexibility in handling, can be backed-off easily, and is easier to thread through equipment when replacement is necessary.

c. Flexible hose, rather than pipes or tubing is used, where minimum space is available for removal, replacement, or handling of lines. It can be backed-off or pushed aside for access to other components.

6. Adequate supports should be used for lines which run from external service or test equipment, or where extensions will be attached for other purposes. In addition to the initial stages of pressure through the line and the weight of the external extensions, such supports must withstand the rigors of handling and repeated connection and disconnection.

Electrical Wires and Cables

1. The layout and routing of cables and wires should be predetermined and made as simple and functionally logical as possible by:

a. Combining conductors into cable wherever practical.

b. Combining conductors into harnesses wherever cables are not used.

c. Minimizing, in turn, the number of wires, harnesses, and cables.

d. Segregating conductors into and within cables or harnesses according to their functions and relationships to replaceable equipments.

2. Conductors should be coded and labeled:

a. In accordance with the provisions under "Connector Requirements," page 192.

b. So that each conductor is identifiable throughout the length of each cable or harness, and is uniquely identifiable wherever tracing is required.

c. So the codes and labels used correspond with those of connector designations, test point designations, and the function of the connector.

3. The mounting of electrical wires, harnesses and cables should insure that adequate accessibility is provided to raceways, conduits, junction boxes, etc.

4. Electrical wires and cables should be routed over, rather than under, pipes or fluid containers.

5. The wire and cable route should be away from or suspended over areas where fluids are likely to drip.

6. Electrical wires and cables should be suspended in those areas where fluids are likely to accumulate, e.g., pans and trenches, under floorboards, etc.

7. Lead lengths should be as short as is consistent with the task at hand, but sufficiently long to permit:

   a. Easy connection and disconnection, with enough slack to back the wire away from the point of attachment to facilitate removal of the unit.

   b. Sufficient slack for at least two (preferably three) replacements of terminal fittings, electrical considerations permitting.

   c. Movement of units which are difficult to handle in their mounted position to a more convenient position for connection or disconnection.

8. Leads should be mounted so they:

   a. Are separated to provide adequate clearance for the technician's hand or any tool required for checking or connection.

   b. Are oriented, where possible, in such a manner as to prevent erroneous connection or "crossing."

9. Extension cables should be planned, designed, and provided as necessary to:

   a. Increase the efficiency and ease of maintenance.

   b. Avoid removal of assemblies or components for testing.

   c. Allow each functioning unit to be checked in a convenient place.

d. Allow support equipment to be parked or set in a convenient place.

e. Serve as many related functions as possible, yet avoid the possibility of misuse or misconnection.

Mounting and Packaging

1. The majority of parts, items, and assemblies can be located and packaged in a variety of ways and places. The final arrangement should be based upon the following factors for ease of maintenance and training:

a. Accessibility preferences.

b. Standardization considerations.

c. Reliability figures and factors, as a basis for access requirements.

d. Operating stress, vibration, temperature, etc.

e. Requirements for built-in test and malfunction circuits or indicators.

2. The peculiar characteristics of each item or module with particular reference to:

a. Item size, weight, and clearance requirements.

b. Item fragility or sensitivity and resultant protection needs.

c. Item servicing, adjusting or repair needs and procedures.

d. Clearance requirements for removing and replacing each item.

e. Tool access and clearance requirements for each item fastener, connector, test or service point, etc.

f. Specific factors such as critical lead length, weight balance, heat dissipation, etc., which may hinder personnel in carrying out their tasks.

3. The layout and packaging of components, subassemblies or assemblies should maximally facilitate the required or expected maintenance operations by:

a. Minimizing place to place movement of the technician during servicing, checkout, or troubleshooting.

b. Minimizing the need for the technician to retrace movements or steps during servicing, checkout, or troubleshooting.

c. Minimizing the number of component or item inputs and outputs.

d. Packaging the equipment so the technician has the option of replacing an individual item of a group, or the whole group in accordance with the maintenance philosophy.

e. Providing new fastener or bracket assemblies on spare components where the old ones are likely to be lost or damaged.

f. Avoiding undue sequential assembly that requires sequential disassembly to accomplish maintenance.

g. Using sliding racks, or hinged assemblies, to allow maximum accessibility.

h. Being organized according to maintenance specialties, so that maintenance performed by one specialist does not require removal or handling of equipment maintained by another specialist--particularly where such equipment is of a critical nature or its maintenance requires highly specialized skills.

4. Parts, subassemblies, assemblies, etc., should be mounted so that:

   a. The manner of mounting satisfies accessibility.

   b. Fasteners employed satisfy preferences and requirements under "Fasteners," (page 206).

5. Mounting fixtures, brackets, etc., should be designed so:

   a. Only interconnecting wire and structural members are permanently attached to units; all other fixtures should be removable for ease of maintenance.

   b. Fixtures which are built into the chassis are either strong enough to withstand usage by personnel ov _ the life of the system or are removable.

   c. Mounting is compatible with the size and weight of the part, to prevent lead breakage or similar damage from fatigue under personnel handling stress.

6. Straps and brackets should be used:

   a. Which are thick or rounded enough so that they have no sharp edges.

   b. Which are twist- or push-to-lock mounting type for small components; such brackets should be designed so:

      (1) Locking studs are visible when the component is in place.

      (2) Locking screws or dimples are provided as necessary to ensure security of the mount.

7. Supports, guides, and guide pins should be provided as necessary to assist handling, aligning, and positioning of units.

8. Bottom-mounted aligning pins should be used for components which are light enough to be lifted and positioned easily--e.g., weigh less than 20 pounds for ease of operator handling.

9. Bottom-mounted aligning pins should not be used for heavy components.

10. Side-aligning devices or brackets should be used for heavy components, so that the component can be slid rather than lifted into and out of place.

11. Shock mounts should be used, as necessary, to:

   a. Eliminate vibrational fluctuations in displays, markings, etc., which will cause error in operator reading, as well as to protect fragile or vibration-sensitive components and instruments.

   b. Control sources of high or dangerous noise and vibration for effective human performance.

12. Hinged bars are useful for tieing down and permitting access to a number of small components at one time.

13. Where blind mounting is required, the inaccessible side should be secured with mounts which:

   a. Allow exceptionally easy mating.

   b. Do not require access to friction lugs, tongue and groove fittings, etc.

14. Mounting of components, modules and parts should be designed to prevent their being inadvertently reversed, mismated or misaligned during installation or replacement.

15. While components of the same form, function and value should be completely interchangeable throughout the system, components of the same or similar form, but of different functional properties, should be:

a. Mounted with standard orientation throughout the unit.

b. Readily identifiable, distinguishable, and not physically interchangeable.

16. The rapidity, accuracy, and ease of maintenance, particularly troubleshooting, are proportional to the amount of color coding, marking and labeling employed. These are the most direct links between the designer and repairman, and should be used as fully as possible to explain arrangement, functions, and relationships among items. There are no hard and fast rules for coding and labeling as a function of, or part of, packaging; the effectiveness of such efforts depends largely upon the care and ingenuity of the designer. Codes and labels used on and within equipment packages will be:

a. In accordance with the principles for coding and labeling.

b. In keeping with test and service point coding and labeling.

c. Consistently and unambiguously used throughout the system.

d. Of such a nature as to be easily read and interpreted.

e. Durable enough to withstand expected wear and environmental conditions.

f. Coordinated and compatible with:

(1) Codes and labels on related test and service equipment.

(2) Other coding and labeling within the system.

(3) Related job aids, instructions, handbooks and manuals.

17. For identification purposes, codes and labels should be provided on and within the packaging arrangement as necessary to:

a. Outline and identify functional groups of equipment.

b. Identify each item or part by name or common symbol.

c. Identify each test or service point, and the sequence in which used.

d. Identify the value and tolerance of parts such as resistors. This identification should be direct rather than in color code where possible.

e. Indicate the direction of current or fluid flow to aid systematic elimination of possibilities when troubleshooting without continuous cross-reference to schematics.

f. Indicate "maintenance highways" to guide the technician through routine processes.

g. Indicate the weight of units over 45 pounds.

h. Point out Warning and Caution areas.

i. Present an outline procedure not made obvious by design, and to supply whatever information is necessary for troubleshooting and maintenance.

j. Allow the presentation or recording of historical data where practical, particularly to:

(1) Display periodic readings at test points to allow development of trends where these are fundamental to maintenance decisions.

(2) Permit recording of replacement dates or other data necessary to replenishment requirements or preventive maintenance.

18. Assemblies, modules, parts, etc., should be packaged and mounted so that:

a. Adequate tool access and wrenching space is provided around fasteners.

b. Adequate space is provided for use of test probes and other service or test equipments.

c. Components to be serviced or repaired in position are at the most favorable working level, i.e., between hip and shoulder height.

d. Maintenance required on a given unit or component can be performed:

(1) With the unit or component in place, where possible.

(2) Without disconnection, disassembly or removal of other items.

e. All replaceable items, particularly disposable modules, are removable:

(1) Without removal or disassembly of other items or units.

(2) By opening a minimum number of covers, cases, panels, etc.

(3) Without hindrance from structural members or other parts.

(4) Along a straight or slightly curved line, rather than through an angle or more devious course.

f. All heavy, large or awkward units are located so they:

(1) May be slid out or pulled out rather than lifted out.

(2) Do not prevent access to other removable items.

(3) Are mounted on sliding drawers, racks, etc., wherever practicable.

g. When it is necessary to place one unit behind or under another, the unit requiring most frequent maintenance is most accessible.

h. All chassis are completely removable from the enclosure with minimum effort and disassembly.

i. Structural members of items, chassis or enclosures do not prevent access to removable items, their connectors or fasteners.

j. Removal and replacement require minimal tools and equipment, and only common hand tools where practicable.

k. Rapid and easy removal and replacement can be accomplished by one man, two men, or handling equipment, in that order of preference.

l. Irregular, fragile or awkward extensions such as cables, hoses, etc., are easily removable before the unit is handled; such protrusions are easily damaged by personnel and make handling difficult.

m. Handling and carrying can be done efficiently by one man.

(1) Removable items should weigh less than 45 pounds.

(2) Difficult to reach items should weigh less than 25 pounds.

n. Items over 45 pounds are designed for two-man handling.

o. Hoist lugs are provided for assemblies over 90 pounds.

19. The design, packaging, and mounting of components, units, parts, etc., should provide the maximum protection for personnel against injury or damage.

20. Items should be located, packaged, mounted, and shielded so that access to them. adjacent items, or associated fastener can be achieved without danger to personnel from electrical charge, heat, sharp edges or points, moving parts, chemical contamination or other hazards. Specifically, design, packaging and mounting should be such that:

a. Commonly worked on parts, fasteners, service or test points, etc., are not located near exposed terminals or moving parts for personnel protection.

b. Guards or shields are provided to prevent personnel from coming into contact with dangerous moving parts or injury potentials.

c. Ventilation holes in equipment are located and made small enough to prevent insertion of fingers, tools, etc., into hazardous areas, e.g., 1/4" diameter holes will exclude fingers.

d. Tool guides are provided to allow safe manipulation of points adjacent to high voltages or other hazards.

e. Capacitors, exhaust pipes or other parts which retain heat or electrical potential after the equipment is turned off are located or shielded so personnel cannot contact them accidentally.

21. Adjustment and alignment devices should be mounted so they cannot be inadvertently actuated by the technician.

22. Small removable pins, caps, covers, etc., should be attached to prevent loss or damage.

23. Vital, fragile, sensitive, or easily damaged components should be located, arranged and shielded so they will not be:

a. Used for handholds, footholds, or rests.

b. Damaged by flying particles, loose objects, or movements of personnel or tools during maintenance.

Optical Material

1. Instruments should be sealed with gaskets whenever possible.

2. Humidity indicators should be provided on sealed instruments to permit proper cycling of purging operations.

3. Optical equipment should be designed, utilizing the modular design concept, i.e., the interchangeability of optical assemblies within an instrument or optical modules that have multiple application in equipment.

4. Built-in aligning devices and other aids should be used wherever possible for ease of positioning optical elements.

5. Quick-release methods of removing optical instruments should be used wherever practical.

6. Whenever possible, optical instruments should be provided with built-in collimation features to allow field adjustment.

7. Where periodic purging and charging of optical instruments is required, an instruction plate indicating time interval and pressure requirements should be provided on the instrument.

8. Windows should be provided for all exposed optical surfaces.

9. The use of slotted lens retainers should be avoided wherever possible.

10. The use of long, uninterrupted threads for lens retainers should be avoided.

11. Purging and charging fittings should be accessible for required maintenance.

12. Readily accessible openings should be provided to facilitate replacement, adjustment, and cleaning of reticles.

13. Light bulbs should be located in an accessible location with sufficient hand clearance to allow removal and replacement by the hand of the 5th to the 95th percentile soldier.

14. Light bulbs should be removable and replaceable without the removal or disassembly of other components of ancillary equipment.

15. The operator should be able to remove and replace light bulbs from the side of the optical device facing him.

16. Bulb retaining bases should be chain mounted to preclude their loss when removing and replacing light bulbs.

17. Light bulb receptacles should be clearly identified to indicate the relationship of the receptacle to the sight or sight reticle that it is illuminating

Test and Service Points

1. In order to make testing and servicing as simple as possible, the recommendations of this section should be considered by the designer.

2. Distinctively different connectors or fittings should be provided for each type of test or service equipment, probe, grease, oil, etc., to minimize the likelihood of error or misuse in the application of these.

3. Requirements for separate funnels, strainers, adaptors, and other accessories should be avoided. Where practical, these should be built into the equipment or service equipment, so they need not be separately handled.

4. Test points should be combined, where feasible, into clusters for multi-pronged connectors, particularly where similar clusters occur frequently.

5. Templates or overlays should be provided where they would usefully expedite the use of different test procedures which utilize the same set of test points.

6. The maximum use of color codes, guidelines, symbols and labels should be made to facilitate following logical test routines among the test points.

7. Test points should be arranged on a panel or other surface according to the following criteria, listed in order of priority:

   a. The type of test equipment used at each point.

   b. The type of connector used and the clearances it requires.

   c. The function to which each point is related.

   d. The test routines in which each point will be used.

   e. The order in which each will be used.

8. Lubrication points should be provided to avoid disassembly of equipment; but if such points are not feasible, easy access should be provided for direct lubrication.

9. In order for the operator to best utilize the test and service points on equipment, the following criteria is recommended for consideration by the designer. These test and service points should be provided, designed and located:

a. According to the frequency of use and time requirements for use.

b. So that there will be a minimum of disassembly or removal of other equipments or items.

c. On surfaces or behind accesses which may be easily reached or readily operated when the equipment is fully assembled and installed.

d. To be clearly distinguishable from each other; where necessary use color coding and labeling to ensure this.

e. So that test points and their associated lables and controls face the technician.

f. So that adequate clearance is provided between connectors, probes, controls, etc., for easy grasping and manipulation. The following minimum clearances are recommended:

(1) 0.75" when only finger control is required.

(2) 3.0" when the gloved hand must be used.

g. So they offer positive indication, by calibration, labeling or other features of the direction, degree and effect of the adjustment.

h. With guards and shields to protect personnel and test or service equipment, particularly if the equipment must be serviced while running.

i. At a central panel or location, or at a series of functionally autonomous panels and locations.

j. To avoid locating a single test or service point in an isolated position; such points are most likely to be overlooked or neglected.

k. With lead tubes, wires, or extended fittings to bring hard-to-reach test and service points to an accessible area.

l. To overcome accessibility deficiencies resulting from critical lead lengths and similar constraints.

m. With windows to internal items requiring frequent visual inspections, e.g., gauges, indicators, etc.

n. With tool guides and other design features to facilitate operation of test or service points which require blind operation.

o. Within easy functional reaching or seeing distance of related or corresponding controls, displays, fittings, switches, etc.

p. Away from dangerous electrical, mechanical or other hazards. A hand's width (4.5") separation should be provided from the nearest hazard, and provide guards and shields as necessary to prevent injury.

q. So they are not concealed or obstructed by the hull, turret, brackets, other units, etc., to eliminate the need to disassemble, remove, or support other units, wires, etc., to test, service or troubleshoot.

10. Where adjustment controls are associated with test and service points, they should be designed and positioned so that:

a. They are located on a single panel or face of the equipment, or on a minimum number of functionally independent panels.

b. They are capable of being quickly returned to the original settings, to minimize realignment time if they are inadvertently moved.

c. Those that require sequential adjustment are located in the proper sequence and marked as necessary to designate the order of adjustment.

d. Adjustments are independent of each other whenever possible.

e. Adjustment procedures are clear and straightforward, and do not require conversion or transformation of related test values.

f. Knobs are used in preference to screwdriver adjustments; the latter are generally unsatisfactory from the standpoint of easy manipulation and the requirement for tools.

g. Adjustability is avoided whenever the part values will not change during the life of the equipment or that an out of tolerance will not affect the system in any manner.

11. The following types of adjustment are to be avoided except where their use will considerably simplify the design or use of the equipment:

a. Extremely sensitive adjustments.

b. "System adjustments," e.g., a component or system should be designed so that components can be replaced without harmonizing or recalibrating the whole system.

c. Harmonizing or "mop-up" adjustments, e.g., those that require "A" or "B" to be readjusted after A, B and C have been adjusted in sequence.

Test Equipment

1. Regardless of the engineering sophistication of the device, unless the technician recognizes it as being useful, reliable, and operable, he will avoid using it, and the design effort is, for all practical purposes, wasted. In order to design for usability, the designer should understand that:

a. Technicians are trained to use complex devices, however, they occasionally forget what they learn.

b. Technicians avoid using devices they do not understand or find difficult to operate.

c. Supervisors hesitate to let technicians use expensive, complex equipment when the operation of the equipment is not simple or self-evident.

d. When test equipment is overly complex and difficult to operate, the technician:

(1) Must spend considerable time and effort to learn to operate it.

(2) Tends to make errors in usage.

(3) Can only learn to operate a small number of devices well.

(4) Finds that habits developed with one device interfere with his learning to use or operate another device.

e. Military testers which are drab, unattractive, and appear to be rugged, actually get rougher treatment than those which look fragile or have eye appeal. Therefore, it is recommended that testers be designed to look no tougher than they are, and to compensate for the rough treatment they are likely to receive.

2. The following list provides common complaints or reasons for not using available test devices. Each of these is a result of inadequate consideration of the user during design, and should be avoided in the design of new devices:

a. The device was too clumsy. heavy or awkward to carry to the job.

b. An unnecessarily large number of different test devices existed.

c. Procedures and displays were inconsistent from device to device.

d. There was confusion as to the accuracy, operation, or purpose.

e. The device was inaccurate, unreliable, or too often out of tolerance.

f. Calibration was too difficult and kept the device out of use too often.

g. The device was not compatible with the tested equipment--e.g., connectors were too loose or too hard to reach, and leads were not long enough, or work space was too small for use of the device.

3. In order to best utilize the human with respect to the test equipment being used, data should be considered regarding the maintenance environment in which testing is to be done, particularly with regard to:

a. The environmental extremes to be withstood by the device operated by the human.

b. Maintenance procedures and policies of the potential system users.

c. Symbols, codes, etc., commonly employed by or familiar to the user.

d. Methods of information presentation, data collection, or maintenance feedback employed by or familiar to the user.

e. Purposes for which the tester will be employed, in terms of what the technician must do with the information obtained from the tester.

f. Tasks involved in use of the tester from maintenance task assignment to return of the tester to storage.

g. Manner of transport of tester from storage to place of application to include:

(1) How far it must be transported, and by what means.

(2) The clothing or other encumbrances the technician will be wearing.

4. To facilitate ease of understanding and increase operator efficiency, instructions should be provided:

a. On the face of the tester, in the lid or in a special compartment.

b. In a step-by-step fashion, numbered or lettered in serial order.

c. In easy view while the device is operated.

d. In simple language, avoiding uncommon terms or symbols.

e. As complete and detailed as required, but strictly job oriented.

f. Which are large enough to be clearly and easily read in poor light.

g. In larger type or in color codes for emphasized material.

h. With a distinguishable title where more than one instruction list is required; color coding should be considered also.

i. As a reminder that the device must be calibrated, especially if calibration is required before each usage or change in usage.

5. A signal should be provided to indicate when the test equipment is warmed up.

6. A simple check should be provided to indicate when the equipment is out of calibration or is otherwise not functioning properly.

7. Exact values should be presented on test equipment displays, rather than indications which require multiplication of other transformation of display values.

8. Whenever more than one scale must be in the technician's view, they should be clearly differentiated from each other by labeling and color coding to their respective control positions.

9. Selector switches should be used on test equipment instead of a number of plug-in connections.

10. Devices such as circuit breakers and fuses should be employed to safeguard against damage if the wrong switch or jack position is used.

11. Written warnings should be provided on the tester to insure that the test equipment will be turned off when testing is completed.

12. The purpose of the tester should be indicated on the outer surface of the equipment.

13. A label should be provided on accessories associated with the test equipment that the technician must use.

14. Fasteners or holders should be provided in storage compartments for test equipment accessories.

15. Portable test equipment should be shaped for convenient storage and handling.

16. Handles on the outside case of portable test equipment should be recessed or hinged to conserve storage space.

17. Adequate stowage space should be provided in the lid or cover of test equipment for storage of all removable items such as leads and adaptors.

18. Storage space for test equipment instructions should be provided on or within the test equipment.

19. For ease of handling and utilization by the technician, test equipment should not be bulky or overweight. The following principles should be considered by the designer:

   a. Stands or casters for devices over 30 pounds should be provided for use.

   b. Wheels, casters or hoist-lifting should be provided for devices over 90 pounds.

   c. Devices should be of rectangular shape so they can be easily stored.

20. Handles should be provided which:

a. Are in accordance with "Handles," (Page 212).

b. Allow the device to be easily handled and carried.

c. Are recessed or hinged for folding to reduce storage space.

d. Are shaped to fit the hand and knurled to ensure a secure grip.

21. Hooks or other devices should be provided on the tester or on the prime equipment to enable attachment of the test equipment when in use.

22. The weight and dimensions of portable test equipment should not exceed those listed below:

	Operability		Portability	
	Hand-Held		One-Man	Two-Men
Dimensions:	Optimum	max	max	max
Weight (lbs)	3	5	25	90
Height	2"	4"	18"	19"
Length	8"	10"	18"	-
Width	4"	5"	10"	-

SAFETY

General Principles of Human Behavior and Safety

1. Safety is of primary concern and should be reviewed and applied in terms of, but not limited to, the following:

  a. Hazard classification.

  b. Electrical and electronic safety factors.

  c. Mechanical safety factors including hydraulics and pneumatics.

  d. Toxicity.

  e. Radiation.

2. There are a number of principles concerning human behavior that an equipment designer should consider. The principles listed below will supply, at least, a partial answer to why people make errors, misuse equipment or otherwise engage in unsafe practices. The principles are based on what actually does happen to equipment and how people actually use the equipment in the field. Armed with a knowledge of why people err, the designer can eliminate many, not so obvious, pitfalls in system design.

Principle 1: If insufficient or inadequate equipment is provided, equipment will be improvised or modified at the site in order to get the job done. Improvised equipment generally leads to improvised procedures. Improvised procedures often result in safety hazards.

Principle 2: A weak excuse is enough for some people to do what they please. To do what they please is often to do what they should not do.

Principle 3: People often feel that "it can't happen here." They feel that other people at other locations may get hurt (or damage equipment) by disregarding instructions, but "not us." Therefore, foolproof procedures are necessary where possible. Since procedures are based upon the design of equipment, it is the basic design which permits foolproof procedures to be developed.

Principle 4: Corrective action on a problem does not always mean the end of the problem. The action taken may not be sufficient, appropriate, or aff[illegible] the real cause of the problem. It might not completely prevent it from recurring elsewhere or in some other way.

Principle 5: No matter how simple and foolproof it looks on paper, try it before finalizing the design.

Principle 6: If the implicit response of the equipment is wrong, it will eventually produce some wrong responses.

Principle 7: A warning note in the appropriate technical manual usually will not overcome a safety problem; it is of only limited and supplementary value to reduce the probability of mishap. People may not have read, remembered, or even known where to find such warning notes.

Principle 8: Some people have to see equipment get damaged by inadequate task performance before they take their assignment seriously and do it thoroughly and carefully.

Principle 9: Do not rely upon special training for those who may use the equipment. Not all individuals will receive the "required" training. Some will have had outdated training, related training, or catch-as-catch-can training. Therefore, try to design for safety rather than hope for special safety training.

Principle 10: Some people have to see someone get hurt before they will believe a practice is dangerous.

Principle 11: People sometimes prefer to work under hazardous conditions, as if their bravery makes the job more important.

Principle 12: Tell some people "don't" and they do, notwithstanding the magnitude of personal risk. Instructions alone are not enough to guarantee proper care, operation, and safety.

Principle 13: Expect that the equipment will be used in the wrong way. Study the consequences of doing the job incorrectly. Then design the equipment so that incorrect operation will do minimal damage.

Principle 14: Will the technician damage it or injure himself if he does not know what it is? Be sure that full, understandable, and legible identification is provided.

Principle 15: Bad conditions which are condoned often seem to multiply and interact to produce serious safety problems.

Principle 16: People tend to avoid or eliminate continual sources of difficulty, not always by sensible or logical approaches.

Principle 17: Just as development engineers work the "bugs" out of critical equipment, so must others work the "bugs" out of the task performances of each person assigned to critical tasks. This may be done, for example, by tutoring them as they practice on non-hazardous simulators or inerts. A certain amount of on-the-job training takes place using operational equipment. Mistakes will be made by these partially trained personnel. The original design of the equipment must anticipate such usage and mistakes.

Principle 18: If the designer does not know all of the requirements of the equipment, it is not likely that his design will meet all of them.

Principle 19: In the midst of complex, multimillion-dollar items of equipment, an item of inexpensive and simple construction may seem unimportant, and its use or maintenance may be neglected.

Principle 20: Unfortunately, people must be protected from themselves. Each supervisor must be responsible for certain areas of personnel and equipment safety. An extremely important part of this responsibility is combating foolish shortcuts and deviations from the prescribed procedures.

Principle 21: Abbreviated checklists are good only when the detailed procedures are known. It is difficult to get technicians to leave a checklist and consult the detailed job procedures when they encounter an unfamiliar area. When in doubt, people tend to experiment and fill in the gaps themselves.

Principle 22: Reputations of equipment are important. If there is even a rumor of hazard or difficulty, task performance and use of the equipment may be adversely affected.

Principle 23: An item of equipment which is difficult to maintain may not be kept in a condition to be used when needed. Equipment which is difficult to use will not be used if any substitute is available.

Principle 24: If the equipment is designed in such a way as to be dependent upon communications between crew members, it is susceptible to human error. People are seldom able to recognize that they have not communicated sufficiently until mistakes have been made, and sometimes not even then.

Principle 25: In summary, the designer should remember that most of the reliability problems affecting operational equipment do not represent defects in the equipment itself, but defects in the way in which it is used. To count upon any significant differences in treatment of equipment on

future programs may constitute a form of wishful thinking. It is much better that the worst problems are precluded during original design than to grapple with them after designs are relatively frozen.

INDEX

V

W

DEPARTMENT OF THE ARMY
U. S. ARMY HUMAN ENGINEERING LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND 21005

AMXHE-SYS

SUBJECT: Transmittal of Changes to HEL Standard S-3-65

623731

TO:

Defence Documentation Center

1. The attached pages constitute the first change to the subject document.

2. Pages to be deleted are:

3	6	63	66	69
4	7	64	67	70
5	8	65	68	

3. Pages to be added are:

3	6	63	66	69
4	7	64	67	70
5	8	65	68	

4. The following pen and ink changes will be made to correct minor deficiencies:

   a. Page 75, para. 2a, "cources" to read "sources."

   b. Page 220, para. 1a, add "unless critical circuits are involved."

FOR THE COMMANDER:

JOHN D. WEISZ
Technical Director

14 Incl
as

DDC
MAR 28 1966
DDC-IRA F

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TABLE 1

Body Dimensions

NOTE: Weight in pounds, all other values in inches	Design Values (Percentiles) 5th Nude	Arctic Clothed*	95th Nude	Arctic Clothed*
Weight (pounds)	124	150	192	222
A. Standing				
1. Stature	64.3	67.3	72.6	75.3
2. Eye Height	59.9	61.4	68.1	69.2
3. Ear Height	59.1		67.0	
4. Shoulder Height	52.0	53.7	59.8	61.3
5. Nipple Height	47.0		53.9	
6. Kneecap Height	18.1	19.7	22.1	23.9
7. Penale Height	31.6	—	37.4	—
8. Substernal Height	45.6	—	52.1	—
9. Suprasternal Height	52.7	—	59.9	—
B. Standing				
1. Nasal Root Height	61.0		68.9	
2. Chest Depth	7.2	11.8	9.6	12.6
3. Waist Depth	6.7	10.0	9.4	14.0
4. Buttock Depth	7.6		10.2	
5. Crotch Height	30.0	28.6	35.8	32.6
C. Standing				
1. Chest Breadth	9.9	—	12.4	—
2. Waist Breadth	9.4		12.3	
3. Hip Breadth	12.1	15.8	14.5	18.3
4. Knuckle Height	27.7	—	32.4	—
5. Wrist Height	31.0		36.1	
6. Waist Height	38.3	41.2	44.8	46.4
7. Elbow Height	40.6		46.4	
8. Cervical Height	54.8	57.5	62.7	64.6
D. Seated				
1. Sitting Height	33.5	35.1	38.0	39.9
2. Shoulder Height	21.0	21.8	25.0	25.8
3. Shoulder Elbow Length	12.9	14.6	15.6	16.2
4. Waist Height	7.9		10.4	
5. Thigh Clearance Height	4.8	6.3	6.5	7.5
6. Buttock-Knee Length	21.5	23.5	25.2	26.4
7. Back of Knee Height	15.7	15.8	18.3	17.4
8. Knee Height	19.8	22.4	23.5	25.6
9. Buttock-Leg Length	39.4		46.1	
10. Forearm-Hand Length	17.3	21.3	20.1	22.1
E. Seated				
1. Shoulder Breadth	16.4	18.8	19.6	22.0
2. Elbow-to-Elbow Breadth	15.3	22.8	20.3	26.7
3. Hip Breadth, Sitting	12.7	17.0	15.5	19.7
4. Knee-to-Knee Breadth	7.2		8.8	
5. Breadth of Both Feet	7.0	9.6	8.2	10.4
6. Elbow Rest Height	7.1	6.4	10.8	10.7
7. Eye Height (See Par.5, pg.2)	29.1	29.9	33.5	33.8

*See note on Arctic Clothing Ensemble, Page 10

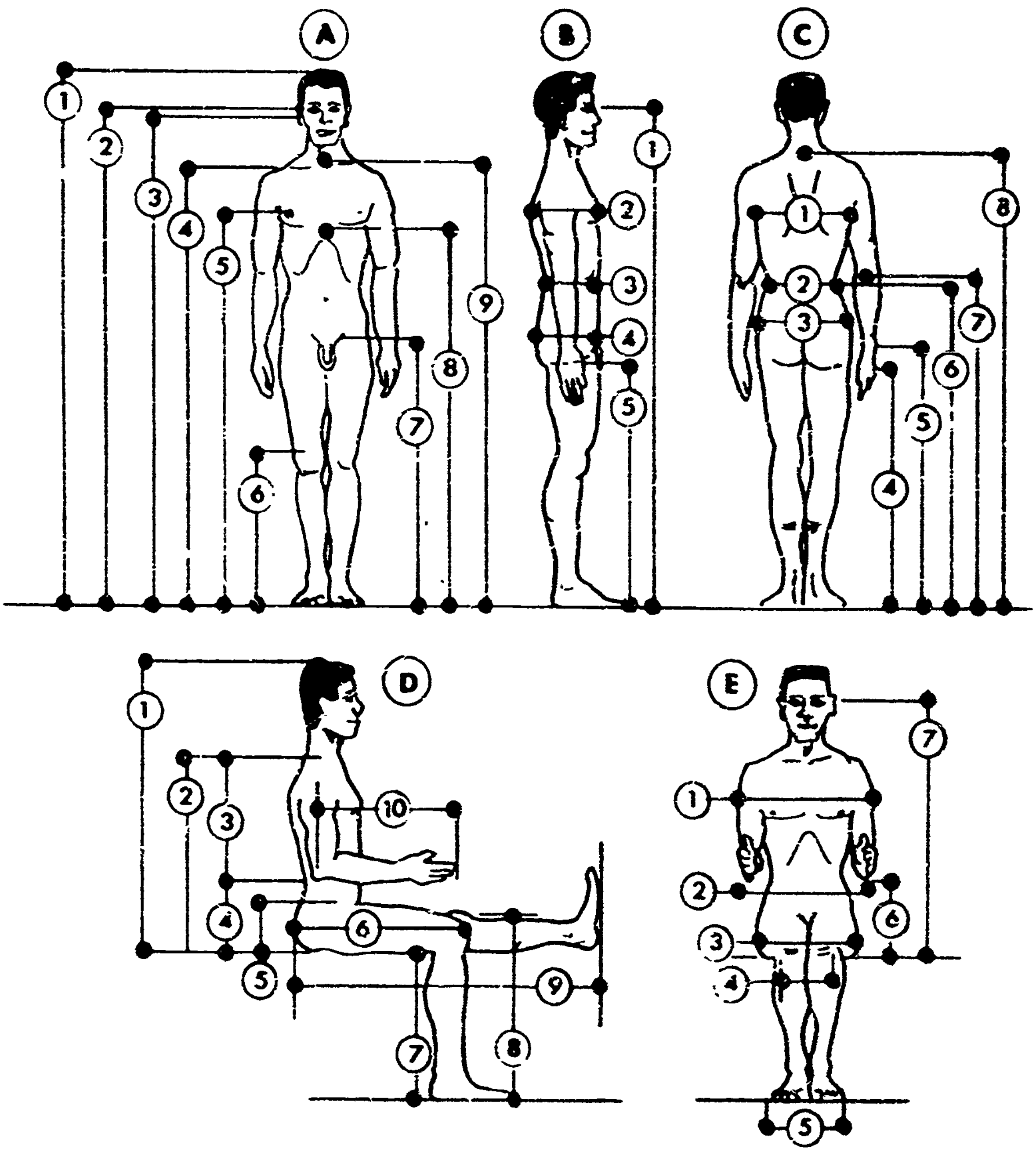

Fig. 1. Body Dimensions

TABLE 1 Continued

NOTE: All values in inches

	Design Values (Percentiles)			
	5th Nude	Arctic Clothed	95th Nude	Arctic Clothed
F. Reach				
1. Functional Reach from Wall	29.4	30.5	34.9	36.6
2. Arm Reach from Wall	31.9	-	37.2	-
3. Maximum Reach from Wall	35.4	-	41.7	-
4. Span	65.0	68.0	75.2	76.6
G. Head				
1. Biocular Diameter	3.3	-	4.0	-
2. Interpupillary Distance	2.3	-	2.7	-
3. Interocular Diameter	1.1	-	1.5	-
4. Nasal Root Breadth	0.4	-	0.7	-
5. Nose Breadth	1.2	-	1.5	-
6. Lip Length	1.8	-	2.3	-
H. Head				
1. Head Breadth	5.6	9.0	6.4	9.0
2. Edge of Right Ear to Left Ear	5.3	-	5.9	-
3. Minimum Frontal Diameter	3.9	-	4.7	-
4. Maximum Frontal Diameter	4.4	-	5.1	-
5. Breadth of the Face	5.1	-	5.9	-
6. Width of the Jaw	3.9	-	4.6	-
7. Ear Protrusion	0.6	-	1.1	-
I. Head				
1. Head Height (from ear)	4.8	6.6	5.6	7.8
2. Minimum Frontal Arc	4.8	-	6.1	-
3. Chin to Nose Length	2.2	-	3.1	-
4. Nose Length	1.9	-	2.5	-
5. Chin to Hairline Length	6.8	-	8.0	-
J. Head				
1. Head Length	7.2	10.9	8.1	10.9
2. Nasal Root to Wall	7.2	-	8.2	-
3. Ear Breadth	1.3	-	1.6	-
4. Ear Length	2.2	-	2.7	-

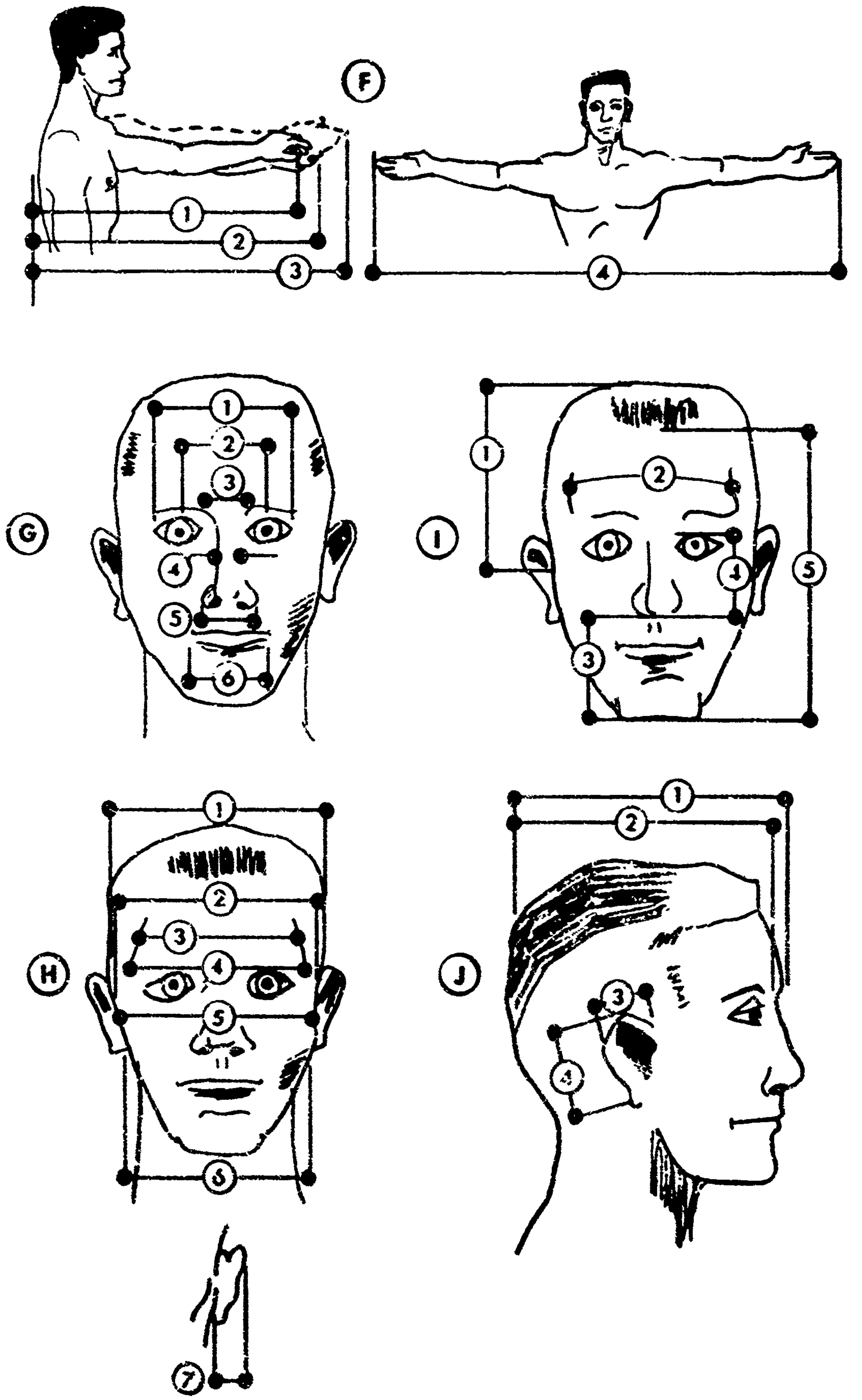

Fig. 1. Continued

TABLE 1 Continued

NOTE: All values in inches

	Design Values (Percentiles)			
	5th Nude	Arctic Clothed	95th Nude	Arctic Clothed
K. Body Circumferences				
1. Neck Circumference	13.3	26.3	15.7	25.4
2. Shoulder Circumference	39.2	49.7	46.6	56.3
3. Chest Circumference	32.9	41.7	40.5	49.4
4. Waist Circumference	26.9	37.6	35.8	47.4
5. Buttock Circumference	33.3	46.0	40.5	54.1
6. Thigh Circumference	18.8	24.6	24.5	29.6
7. Lower Thigh Circumference	13.1	-	16.	-
8. Calf Circumference	12.6	19.4	15.6	22.0
9. Ankle Circumference	7.8	15.0	9.5	17.7
10. Wrist Circumference	6.0	11.8	7.4	13.0
L. Foot				
1. Ankle Breadth	2.7	-	3.2	-
2. Ankle Height (Medial)	3.1	-	3.8	-
3. Ankle Height (Lateral)	2.4	-	3.1	-
4. Foot Breadth	3.5	4.8	4.3	5.4
5. Ball of Foot Circumference	8.9	14.7	10.5	15.5
6. Foot Length	9.7	12.7	11.2	13.3
7. Instep Length	6.9	8.4	8.3	9.0
8. Heel Breadth	2.3	-	3.0	-
M. Hand				
1. Grip Diameter (Outside)	3.7	See	4.4	
2. Grip Diameter (Inside)	1.6	Fig. 4	2.1	
3. First Phalanx III Length	2.5		2.9	
4. Fist Circumference	10.7		12.4	
5. Thickness at Metacarp. III	1.0		1.3	
6. Finger Diameter III	0.8		0.9	
7. Hand Length	6.9		8.2	
8. Hand Breadth at Metacarp	3.1		3.7	
9. Palm Length	3.9		4.6	
10. Hand Breadth at Thumb	3.7		4.4	
11. Digit to Crotch Height	4.0		5.0	
12. Thumb Thickness	0.7		0.8	
13. Thumb Length	2.0		2.6	
14. Third Finger Length	4.2		4.8	
15. Dorsum Length	2.8		3.2	

TABLE 11

REPRESENTATIVE EXAMPLES OF ILLUMINATION REQUIREMENTS

	Illumination Levels (in foot candles) Recommended	Minimum	Lighting source
Perception of small detail under low contrast conditions - for prolonged period of time, or - where speed and accuracy are essential (Examples: small component repair; inspection of dark materials; layout drafting)	150	100	General Service Plus Supplementary
Perception of small detail under conditions of fair contrast - where speed or accuracy are not so essential (Examples: handwriting; electronic assembly)	100	50	General Service and/or Supplementary
Prolonged reading, desk or bench work, general office and laboratory work (Examples: assembly work; record filing)	70	50	General Service and/or Supplementary
Occasional reading, recreation, sign reading - where visual tasks are not prolonged (Example: bulletin board reading)	50	30	General Service or Supplementary
Perception of large objects with good contrast (Example: locating objects in bulk supply warehouse)	20	10	General Service
Passing through walkways, handling large objects (Example: loading from a platform)	20	10	General Service

TABLE 12

SPECIFIC TASK ILLUMINATION REQUIREMENTS

Illumination Levels

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Assembly, missile component	100	50
Assembly, general		
course	50	30
medium	75	50
fine	100	75
precise	300	200
Bench work:		
rough	50	30
medium	75	50
fine	150	100
extra fine	300	200
Business machine operation (calculator, digital, input. etc.)	100	50
Console surface	50	30
Corridors	20	10
Circuit diagram	100	50
Dials	50	30
Electrical equipment testing	50	30
Emergency lighting	--	3
Gages	50	30
Hallways	20	10

*As measured at the task object or 30 inches above the floor.

TABLE 12 Continued

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Inspection tasks, general:		
rough	50	30
medium	100	50
fine	200	100
extra fine	300	200
Machine operation, automatic	50	30
Meters	50	30
Missiles:		
repair and servicing	100	50
storage areas	20	10
general inspection	50	30
Office Work, general	70	50
Ordinary seeing tasks	50	30
Panels:		
front	50	30
rear	30	--
Passageways	20	10
Reading:		
large print	30	10
newsprint	50	30
handwritten reports, in pencil	70	50
small type	70	50
prolonged reading	70	50
Recording	70	50

TABLE 12 Continued

Work Area or Type of Task	Foot Candles* Recommended	Minimum
Repair work:		
general	50	30
instrument	200	100
Scales	50	30
Screw fastening	50	30
Service areas, general	20	10
Stairways	20	10
Storage:		
inactive or dead	5	3
general warehouse	10	5
live, rough or bulk	10	5
live, medium	30	20
live, fine	50	30
Switchboards	50	30
Tanks, containers	20	10
Testing:		
rough	50	30
fine	100	50
extra fine	200	100
Transcribing and tabulation	100	50

Note: Some unusual inspection tasks may require up to 1000 foot candles of light.
Note: As a guide in determining illumination requirements the use of a steel scale with 1/64 inch divisions requires 180 foot candles of light for optimum visibility.

Brightness Ratios

1. The brightness ratios between lightest and darkest areas and/or between task and surroundings should be no greater than:

Condition	Environmental Classification		
	A	B	C
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	*
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	*
Between luminaires and adjacent surfaces	20 to 1	*	*
Between the immediate work area and the remainder of the environment	40 to 1	*	*

*Brightness ratio control not practical

A - Interior areas where reflectances of entire space can be controlled in line with recommendations for optimum seeing conditions.
B - Areas where reflectances of immediate work area can be controlled, but control of remote surround is limited.
C - Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

Glare

1. One of the most serious of all illumination problems is glare or dazzle. Glare not only reduces visibility for objects in the field of view, but causes visual discomfort.

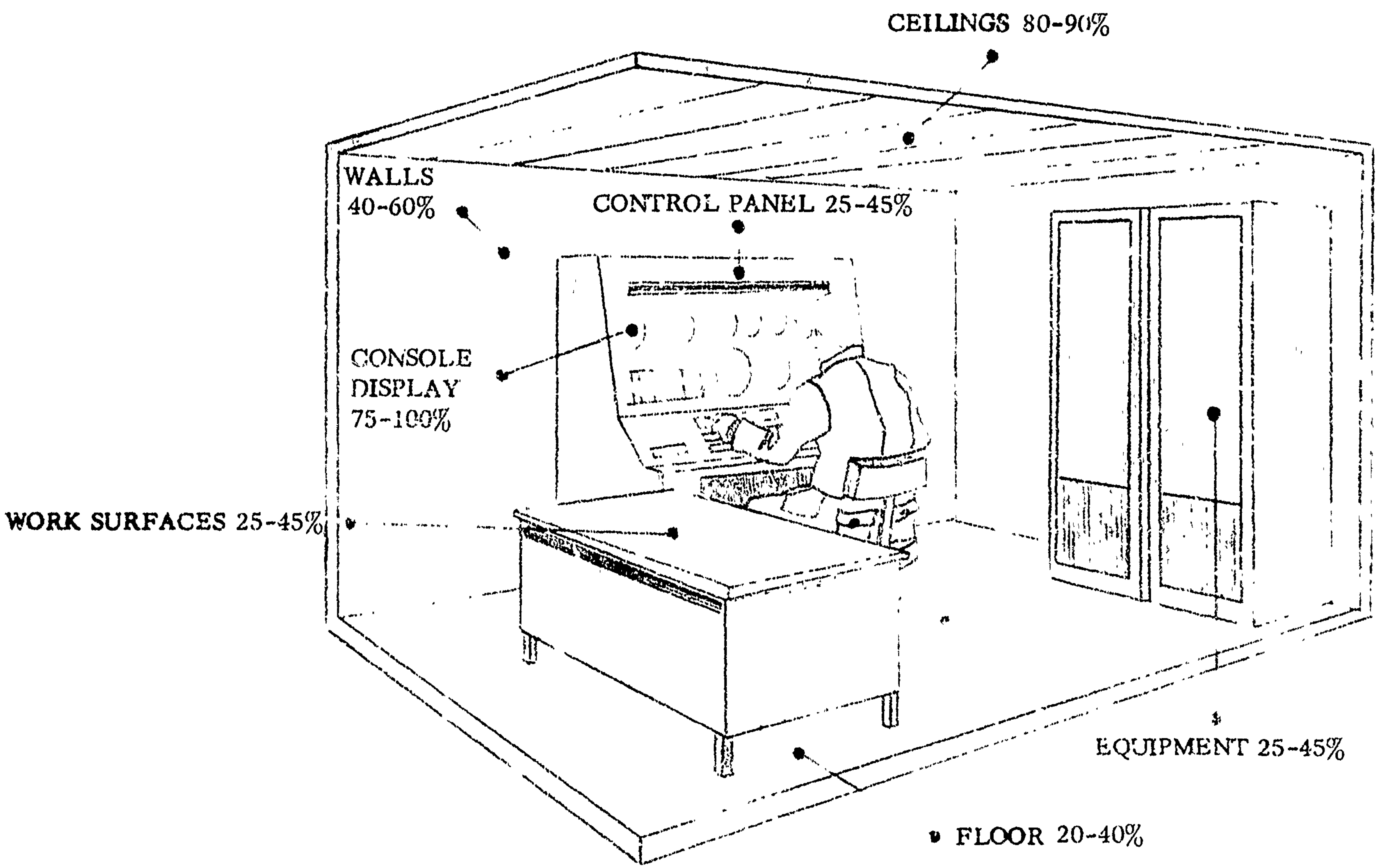

Fig. 25. Work Space Reflectance Values

2. Direct glare refers to a light source within the visual work field and should be controlled by:

a. Avoiding bright light sources within 60° of the central visual field. Since most visual work is on or below a horizontal level from the eye, direct luminaires placed high above the work area minimize direct glare.

b. The use of indirect lighting.

c. Using a greater number of less intense light sources rather than a few intense ones.

d. Using polarized light shields, hoods or visors to block the source in confined areas.

3. Reflected glare refers to reflecting bright surfaces within the visual field and should be controlled by:

a. The use of diffuse lighting sources.

b. The use of surfaces that diffuse rather than specularly reflect incident light.

c. The arrangement of direct light sources so that the viewing angle of the visual work area is not equal to the angle of incidence from the source.

4. The glare control methods outlined above assume that the operator has unaided vision. When eyeglasses are worn they will reflect glare into the eyes if a bright light source to the rear of the viewer is less than 30° above or 45° below the line of sight. Glare will also be reflected if the light source to the rear is within a 20° horizontal deviation from the line of sight.

5. Reflected glare from work surfaces is a common, but frequently overlooked, cause of inefficiency in visual tasks.

Reflectances

1. Generally recommended surface reflectance values for workplaces such as power stations, control rooms, offices and maintenance areas are indicated in Fig. 25.

2. The large surface areas of the space should be non-glossy. Some non-critical small areas such as door frames and molding may be glossy if ease of cleaning is essential.

3. Non-saturated colors such as tints, pastels, and warm grays should be used on all large surface areas.

Color

1. Where current regulations do not specify colors or where the procuring activity does not specify colors, the following colors selected from FED-STD-595 should be used as applicable:

2. Interior Areas and Equipments

Ceiling	27875 White
Console Exterior	24410 Green
Console Interior	37875 White (used only where maintenance and troubleshooting are required within the console. Otherwise, standard requirements for an economical internal protective finish apply.)
Floors	36118 Gray
Handles	37038 Black
Lettering	37038 Black
Panels	26492 Gray
Walls	24410 Green

3. Exterior Equipment

Covers	24087 Olive Drab
Handles	37038 Black
Lettering	37038 or use 37875 White on Olive Drab surfaces
Panels	26492 Gray